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AUG 76 J W STETKAR, M W GOLAY

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USERS MANUAL:
TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND
TOTAL ENERGY SYSTEM RESPONSE SIMULATION

RT 2024

by

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and
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of

The Department of Nuclear Engineering
in association with
The Energy Labroatory
of the
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20. listing of the code. Sample data is included for the execution of a 24-hour dynamic simulation of a TES serving a community of 50,000.

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1.

ABSTRACT

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TDIST, the Thermal Distribution System Simulation Code, is a computer program developed at MIT to aid in the design and dynamic performance analysis of a large integrated Total Energy System (TES) supplying thermal and electrical energy to a multi-consumer-type metropolitan area. Included in this User's Manual are derivations of the detailed consumer energy demand models and of the Thermal Utility System (TUS) component models developed in each of the system analysis subroutines. Comprehensive modelling scenarios are presented to illustrate how these program components are combined to yield a range of steady-state and dynamic system analysis options. Program execution information includes descriptions of the three primary modes of program operation, complete documentation of input requirements and data card formats, examples of available data output options, and a listing of the code. Sample data is included for the execution of a 24-hour dynamic simulation of a TES serving a community of 50,000.
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SPECIAL NOTE ON NOMENCLATURE

For convenience in cross-referencing between the descriptions of the code's operation presented in Section A.3 and the actual listing of the code in Section A.8, all variable names used in this manual are the same as those used in the code, and are defined in Section A.7.

A.1 Introduction

The primary function of the Thermal Distribution System Simulation Code (TDIST) is to aid in the design and performance analysis of a Total Energy System (TES) supplying thermal and electrical energy to a metropolitan area containing a variety of energy consumption categories. To achieve this end, the code is concerned with the steady-state and time-dependent energy flow modelling of up to twenty different energy consumer types and of the thermal utility system (TUS) serving them with high temperature water (HTW) from a central total energy power plant site. Since the major costs of such an integrated energy supply system are particularly sensitive to the TUS design, emphasis is placed upon simulating the time-dependent TUS performance. No provisions are made for specifically modelling the associated electrical energy distribution network, although the community's electrical energy demands are calculated and are included in the overall TES energy supply analysis.

Briefly, TDIST consists of two distinct, but interconnected, modelling packages. The first is a set of building energy flow calculation subroutines which determine the space conditioning, domestic hot water, and non-space-conditioning electrical loads for each of the specified energy consumer types, based upon steady-state demand calculations scheduled over time according to building usage characteristics and

ambient weather conditions. These demands are applied to a range of end-use equipment types available for each building in the community, the aggregate demands of which comprise the time-varying loads to be supplied by the thermal and electrical energy distribution networks. The second modeling package utilizes the computed thermal energy demands and the thermal energy output of the central TES power plant as driving functions for the TUS. Included in the dynamic models of this system's components are descriptions of the major piping loops, the HTW circulation pumps, heat exchangers, thermostatically-controlled fluid flow regulation circuitry, and a central stratified thermal energy storage reservoir designed to smooth the system's thermal energy supply and demand imbalances over a 24-hour duty cycle.

Various conceptually independent segments of these models are developed in separate program units to allow flexibility in their formulation and integration into the two packages. These sub-program units are discussed in detail at a later point when the derivations of the individual system component models are presented. However, a brief overview of the general characteristics of the overall TES model is useful in understanding how each of the sub-units is related to the others and how they are integrated to yield the desired TES behavioral information.

A.2 Overall TES Simulation Model Description

For the purposes of energy demand modelling, it is assumed that all the buildings in the community are aggregated into a set of up to 20 representative energy consumption categories based upon similarities in construction characteristics and usage patterns. Building units typifying each of these consumption categories are further aggregated into from one to twenty-five Consumer Load Centers, the distribution of which reflects the type and intensity of use to which each geographical region within the community is put. Figure A.1 illustrates a unidirectional grouping of these load centers postulated for a typical large U.S. military installation, which is fairly representative of small industrial or suburban civilian communities [1].

The assumed configuration for the TUS piping connecting the load centers to the central power station is shown in Fig. A.2. Each Load Center Heat Exchanger is a single heat exchanger which supplies a load center with water at a temperature consistent with the requirements of the end-use equipment in the buildings which it serves. All thermal energy distribution in the piping loops shown in the figure is through the HTW medium, although the use of low pressure steam generators for certain process heating applications is not precluded in sections of the utility system not included in the TDIST models. The Load Center Heat Exchangers may

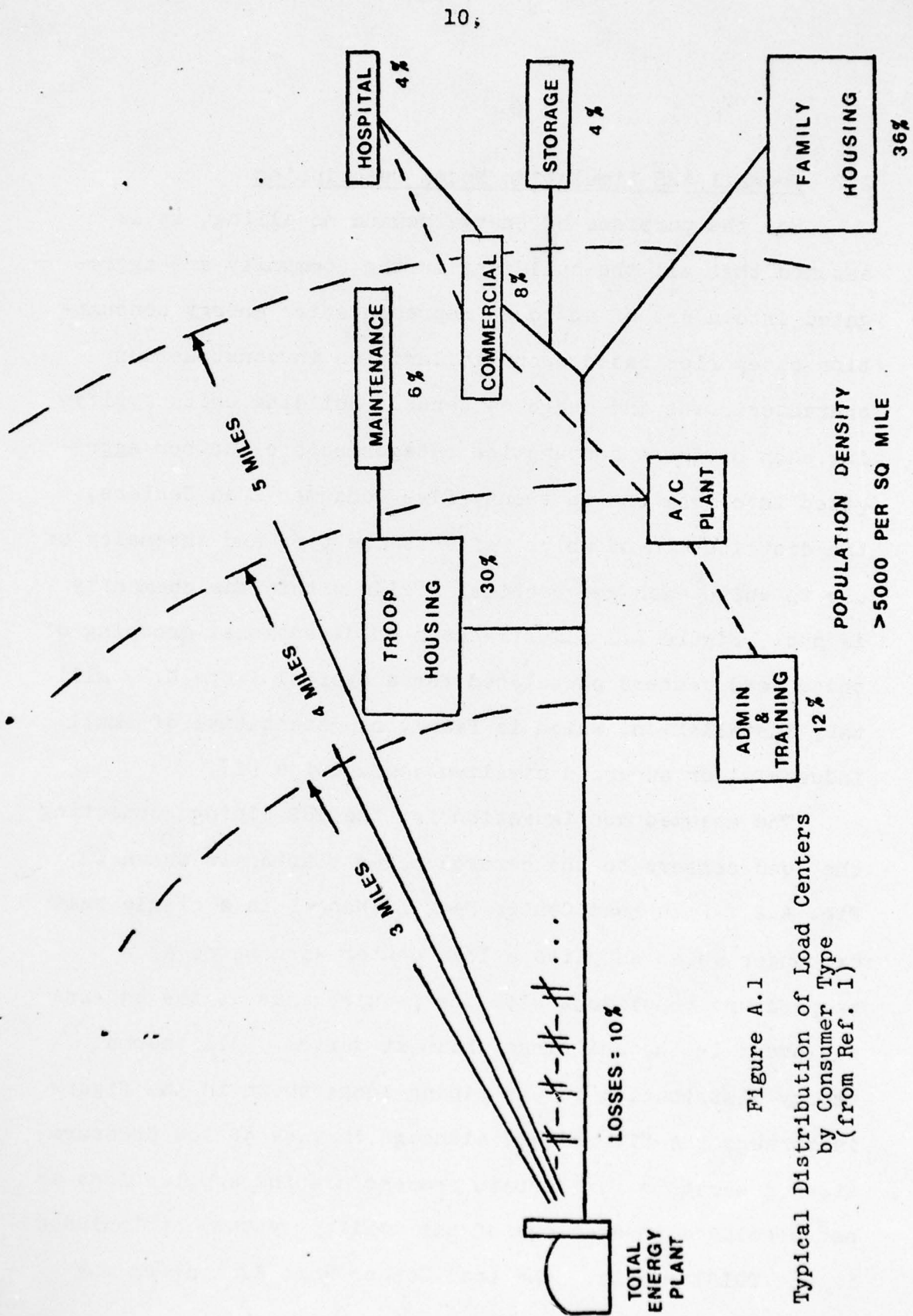


Figure A.1

Typical Distribution of Load Centers
by Consumer Type
(from Ref. 1)

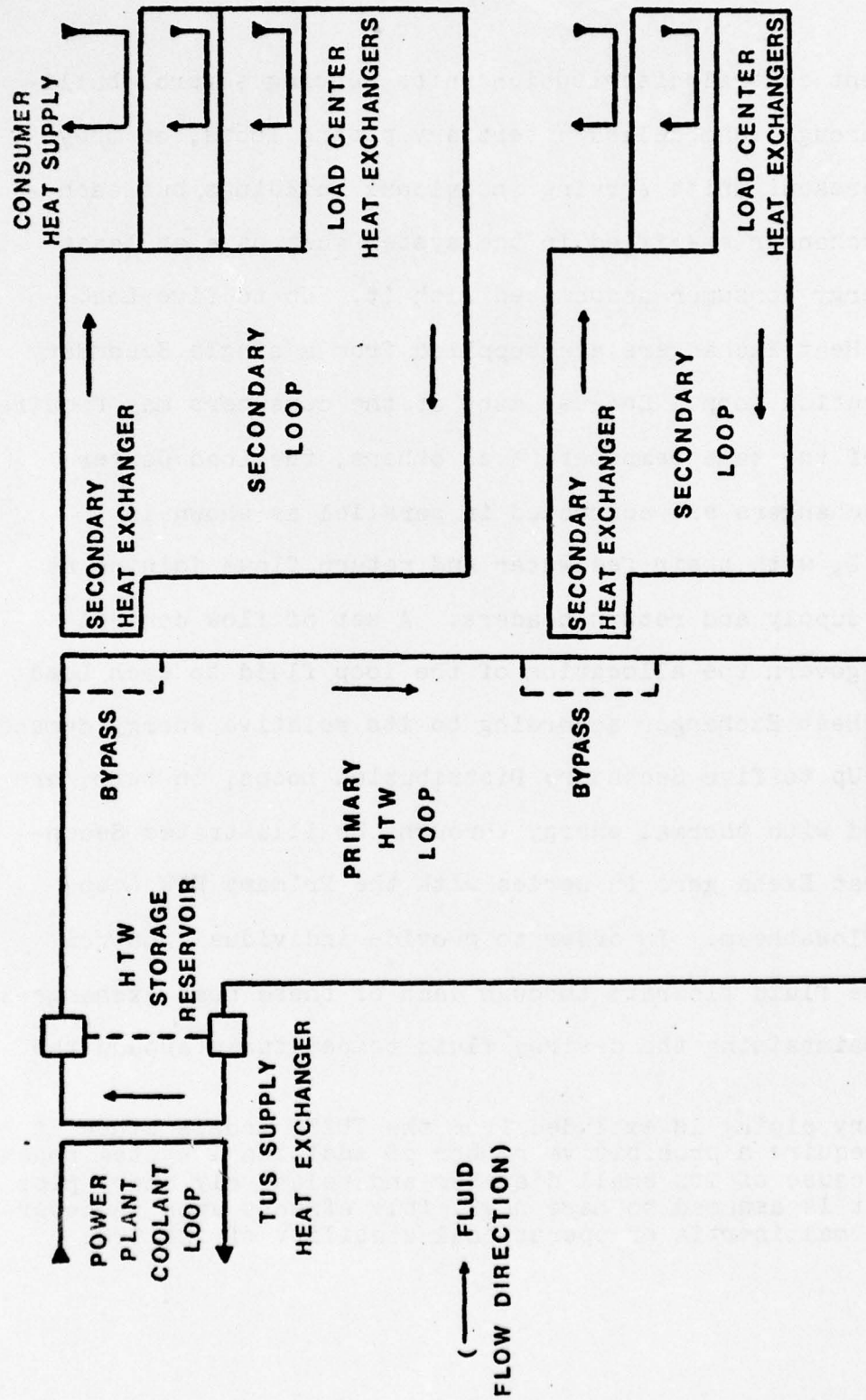


Figure A.2
Thermal Utility System Piping Schematic

represent central distribution units serving several buildings through (unmodelled*) tertiary piping loops, or they may represent units serving individual buildings, but each heat exchanger specified in the system must have at least one energy consumer associated with it. Up to five Load Center Heat Exchangers are supplied from a single Secondary Distribution Loop. Because many of the consumers may require water of the same temperature as others, the Load Center Heat Exchangers are connected in parallel as shown in Fig. A.2, with their feedwater and return flows joining at common supply and return headers. A set of flow control valves govern the allocation of the loop fluid to each Load Center Heat Exchanger according to its relative energy demand rate. Up to five Secondary Distribution Loops, in turn, are supplied with thermal energy through the illustrated Secondary Heat Exchangers in series with the Primary HTW Loop fluid flowstream. In order to provide individual control over the fluid flowrate through each of these heat exchangers while maintaining the desired fluid temperatures around the

*Tertiary piping is excluded from the TDIST models since it would require a prohibitive number of additional system nodes and, because of its small diameter and relatively short pipe runs, it is assumed to have negligible effects upon the overall thermal inertia or operational stability of the TUS.

primary loop, bypass loops are provided around each Secondary Heat Exchanger, with the relative bypass and heat exchanger fluid flowrates governed by control valves set according to the heat exchanger thermal demands. Control over the total primary and secondary loop energy supply rates is accomplished through variations in the various circulation pump pressure settings, adjusting the loop fluid flowrates while maintaining relatively fixed loop fluid temperature distributions.

As is shown in Fig. A.2, the thermal energy Storage Reservoir serves as an interface between the Primary HTW Loop and the system's thermal energy supply at the power plant's TUS Supply Heat Exchanger. Figure A.3 shows a more detailed view of this reservoir, while the schematic Fig. A.4 illustrates the method by which the two different temperature sections are separated for modelling purposes. During periods of low thermal demand and excess thermal supply, the reservoir is charged, with the temperature interface moving into the cold water section, and the hot water volume increases. When necessary, hot water is withdrawn from the tank to supplement the power plant's output. Because modern technology is limited to the production of pressurized steel cylinders of the type shown with dimensions of approximately 20 ft. in diameter and 70 ft. long [2], the actual reservoir would consist of a set of these smaller tanks connected in parallel to

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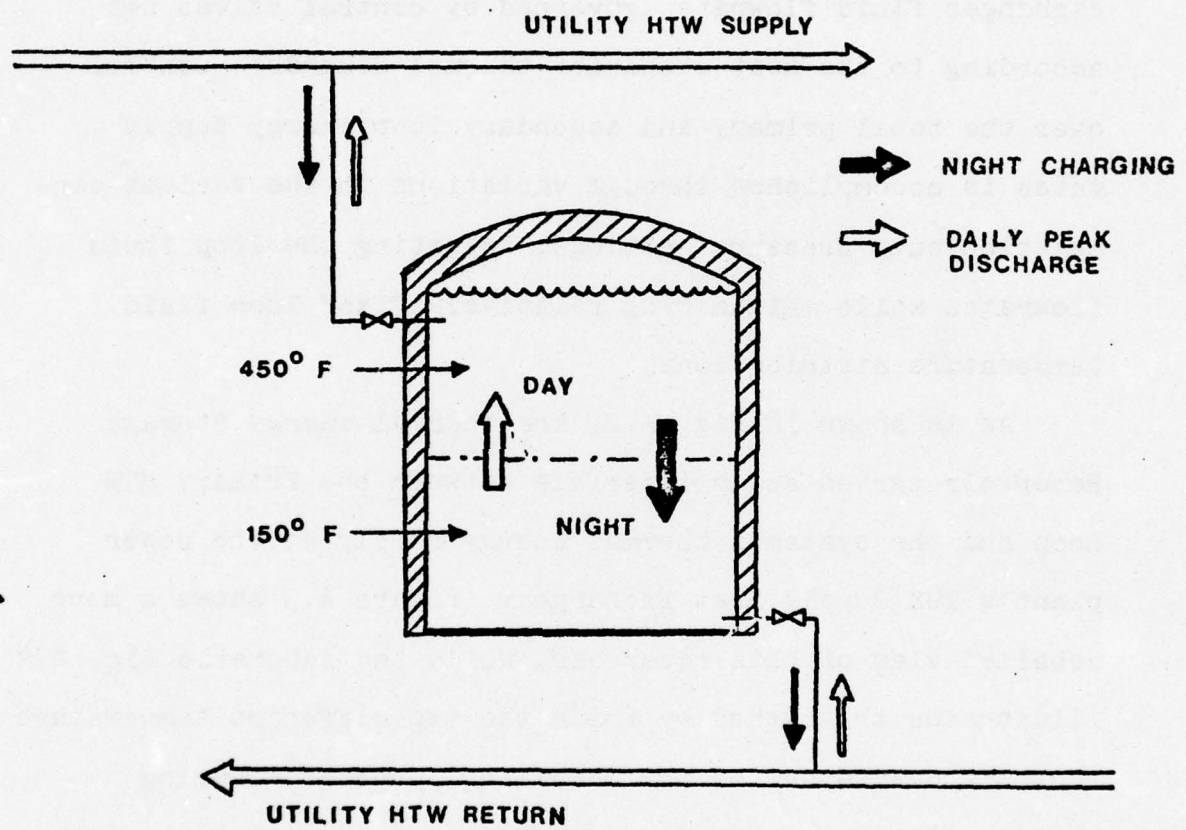
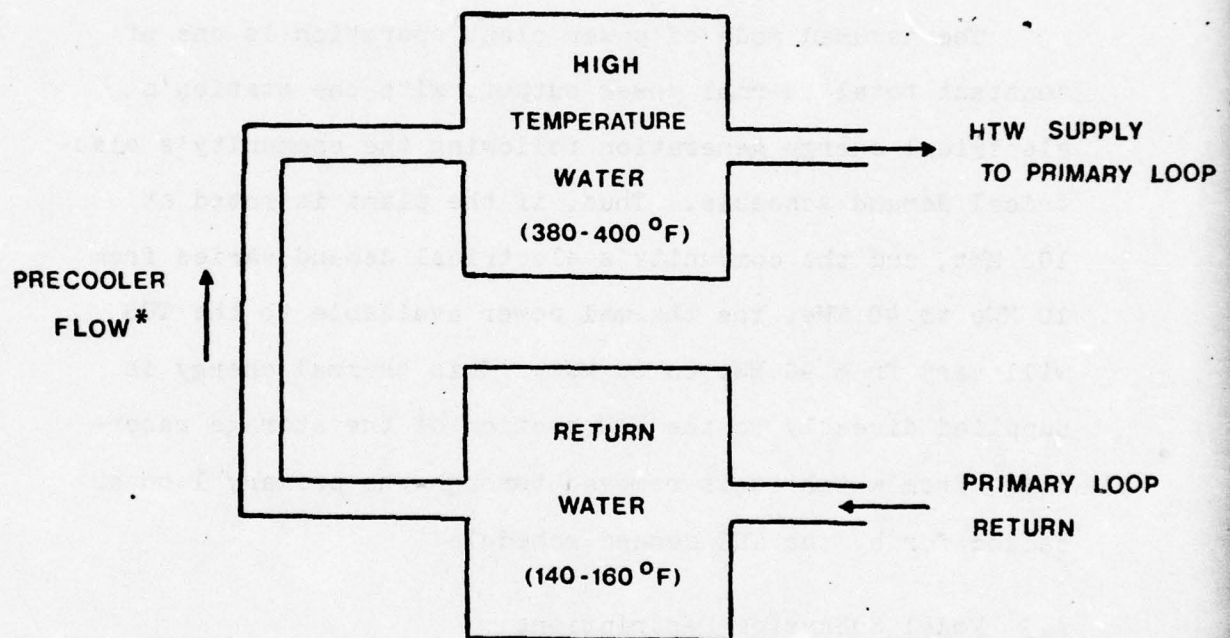


Figure A.3

Underground Stratified Thermal Energy Storage Reservoir
(from Ref. 3)



*Determined independently of Primary Loop flow to allow the storage volume to vary

Figure A.4

Thermal Energy Storage Reservoir Model Schematic

produce a large storage field. European experience with this method of energy storage indicates that minimal mixing between the two fluid temperature regions takes place if charge/discharge cycling times are on the order of 4-12 hours [3].

The assumed mode of power plant operation is one of constant total thermal power output, with the station's electrical energy generation following the community's electrical demand schedule. Thus, if the plant is rated at 100 MWt, and the community's electrical demand varies from 10 MWe to 40 MWe, the thermal power available to the TUS will vary from 90 MWt to 60 MWt. This thermal energy is supplied directly to the HTW section of the storage reservoir, from which it is removed through the primary loop as called for by the TUS demand schedule.

A.3 Model Subsystem Descriptions

As is stated above, the overall energy system model can be broken down into several conceptually independent subsystems whose behavior can be studied separately and then reintegrated into the full model. Table A.1 lists the subsections of the program which are concerned with each of the separate modelling tasks and describes briefly their functions within the total system model; more detailed descriptions and derivations of the specific models used are presented in the following sections.

TABLE A.1

TDIST SUBROUTINES

<u>Subroutine</u>	<u>Function</u>
1. Main (MAIN)	Data input, program flow control, time monitor, thermostat control
2. Input Scaling (CSALE)	Scales input fluid mass flowrates according to case run multiplier (not fully developed)
3. Consumer Heat Flow (QLOAD)	Calculates space heating and cooling loads for all building types
4. Building Load Distribution (DLOAD)	Calculates domestic hot water loads and distributes building total energy demands among specified mixture of thermal and electrical end-use equipment
5. Steady-State System (STDY)	Establishes steady-state flow rates and temperature distribution throughout system
6. Initialization (SET)	Initializes dynamic analysis sections to converged steady-state system conditions
7. Fluid Flowrate (FLOWS)	Calculates instantaneous fluid flowrates throughout system, monitors storage reservoir heat flow
8. System Pressure Drops (PRESS)	Calculates fluid frictional pressure losses, sets circulation pump pressures
9. Dynamic Energy Balance (ENRG)	Sets instantaneous system temperature distribution based upon heat flow analyses
10. Precooler Monitor (PREC)	Monitors heat flow through power plant TUS supply heat exchanger
11. Output (PRV)	Prints system parameters

A.3.1 Energy System Simulation Control (Program MAIN)

To simplify the calculation procedure in each program unit, the entire model system as shown in Fig. A.3 is broken down into a set of nodes whose boundaries are determined by such elements as pipes and heat exchangers having different physical properties, fluid flow and heat transfer characteristics and transient thermal behavior. A typical secondary loop serving three load center heat exchangers thus consists of six nodes: the three load center heat exchangers, two lengths of distribution piping, and one secondary heat exchanger. Appropriate boundary conditions are invoked in each subroutine to ensure the physical continuity of the piping loop being analyzed, but all calculations are performed on a purely nodal basis. All nodes are indexed for simple identification of their parameters and locations within the system, and since heat transfer between the two nodes on opposite sides of a heat exchanger is vital to the dynamic simulation development, each heat exchanger is also indexed separately by both its hot-and cold-side nodes. The program input, for each node consists of its index numbers, codes for its type (pipe or heat exchanger, series or parallel branch, whether or not it contains a circulation pump), its overall heat transfer coefficient, and estimates of the initial fluid mass flowrate, inlet and outlet fluid temperatures, and fluid density, specific heat and viscosity. Additional

distribution system input data includes the initial volumes of the hot and cold regions of the storage reservoir, the HTW storage temperature, and specifications of the power plant coolant mass flowrate, specific heat, and inlet and outlet temperatures at the system supply heat exchanger. The ambient earth temperature is specified for the determination of heat losses from the distribution piping and heat conduction to the earth from the various buildings. Consumer sector input data includes the exposed areas and thermal resistances of all exterior features (walls, windows, roof, basement) of each specified building type within the community, specifications of infiltration crack dimensions and air flow coefficients, the building heights, the wall and roof surface material types, peak ventilation air flowrates, peak internal non-space-conditioning equipment heat generation rate, peak domestic hot water usage rates, shading coefficients and solar absorptivities of the walls and roofs, and the building orientations relative to North. The number of units of each building type served by each load center heat exchanger and the total number of buildings of each type not connected to the TUS are input in conjunction with specifications of the types and distribution of space conditioning equipment to be used in the system. The desired building room temperatures, building usage specifications and domestic hot water demands are provided in the form of hourly schedules and are used in

conjunction with hourly air temperatures, wind velocities and wind directions for the specified time period - in addition to seasonal solar position and radiation intensity data - to determine the hourly energy demands for the buildings, which are applied to the thermal and electrical energy distribution networks after being scaled according to the specified end-use equipment coefficients of performance. Finally, a fixed power plant thermal output power level and electrical generation efficiency are input in conjunction with hourly non-space-conditioning electrical energy demand data (e.g., loading from lights, appliances, motors, etc.) to determine the net energy available from the power plant to supply the building-specific space conditioning and domestic hot water energy demands. Control codes indicating the type of calculation to be made (building load analysis, TUS design initialization, steady-state TUS analysis, full dynamic system analysis), the simulation time step interval, and the desired output frequency determine the overall program flow and information transfer.

. In the building load analysis mode of operation, the code computes and prints out the hourly space conditioning loads and their components for each of the specified building types to allow verification of the building input parameters prior to the use of these demands in the dynamic system simulations. The first hourly set of demands are scaled by the specified end-use equipment coefficients of

performance and the resulting loads are aggregated according to the given distribution of buildings and are displayed at the load center heat exchangers to allow the calculation of TUS system initialization or design parameters to be used as input data for the dynamic simulations.

If only the steady-state TUS analysis is required in a given run (e.g., to check a design for adhering to desired limits on fluid flowrates or temperatures), the model calculates only a single set of consumer loads, applies these loads to specified supply and return temperature conditions at the load center heat exchangers, and determines the resulting steady-state fluid flows and temperature distributions throughout the HTW transmission system based upon specified system thermal and electrical energy supply conditions. (See the section describing Subroutine STDY for a more detailed analysis of the actual calculation procedures used.)

If, as will generally be the case, it is desired to study the dynamics of the TUS behavior over a period of time during which both the energy supply and demand conditions will vary, Program MAIN becomes the overall control and time-monitor for the remainder of the subprograms. Unless a detailed system description including all the nodal flowrates and temperatures for the specified initial conditions is known, the model calculates the steady-state system distributions for these conditions and uses them as the input

parameters to the dynamic calculation subroutines. A clock is set and Program MAIN sweeps the system at a rate fixed by the specified transient time step interval. At each time increment, the previously computed building load distributions are used to yield instantaneous thermal and electrical energy demands through linear interpolation between the hourly data points. These loads are applied to the load center heat exchangers, and nodal energy and momentum transfer calculations are performed to determine the net imbalances during the time step between the system thermal demands and the power plant thermal energy output (given by the total station power rating, less the electrical energy produced to meet the electrical demands).

In addition to performing the program flow control and monitoring functions, Program MAIN also contains the thermostat models which govern the TUS response to thermal energy supply and demand variations. Chosen as temperatures to be monitored by these thermostats are the consumer fluid supply and return temperatures at the load center heat exchangers (to insure uniform operational parameters for the consumers' end-use equipment) and the outlet temperatures on the primary loop side of the secondary heat exchangers (to insure the maintenance of sufficiently high fluid temperatures at the supply to the last secondary loop in the system). At the end of each time step, after the system temperatures have

been adjusted according to the energy transfers occurring during the increment, each of these reference points is checked to determine if the temperatures have exceeded their limits. (Consumer water supply temperatures are allowed to vary ± 5 °F from their initial design values; return temperatures are allowed to vary from the minimum room temperature in any of the buildings served to 5 °F above their initial design values. Primary loop heat exchanger outlet temperatures are allowed to vary ± 5 °F from their design settings.) If any temperature is found to have surpassed its tolerances, steps are taken to re-adjust the loop fluid flowrates to correct the causal energy flow imbalances. To accomplish this re-adjustment, a set of dummy loop fluid flowrates are calculated which satisfy the instantaneous energy demand conditions within the desired loop fluid temperature distributions. Valves in the secondary distribution loops are reset to allocate the total loop dummy fluid mass flowrates among the load center heat exchangers according to their relative energy demands. Independent dummy flowrates are calculated for each of the primary-side secondary heat exchanger nodes based upon their thermal demands and desired inlet and outlet temperatures. The largest of these flowrates is assumed to occur under conditions of no bypass flow (i.e., the total primary loop fluid mass flowrate is applied to one of the heat exchangers),

and bypass flowrates are established around each of the other heat exchangers such that the dummy heat exchanger flowrates are maintained at their calculated values and continuity of the total loop fluid flowstream is insured. (i.e., Any excess fluid over that required to supply the load for a given heat exchanger is shunted around that heat exchanger and re-joins the total loop flow downstream of the heat exchanger outlet). A series of subroutines is then called which calculate the loop circulation pump pressures corresponding to these desired dummy flowrates, and the existing pump pressures are adjusted to accelerate or decelerate the observed fluid flowrates over a period of time governed by the input pump response sensitivity factor. Valve models adjust the relative heat exchanger flowrates to the desired flow split conditions. (See Subroutine FLOWS for further details of the adjustment process). The system thus responds to load variations primarily through adjustment of the loop fluid flowrates, allowing constrained fluid temperature variations to provide secondary compensation through changes in the instantaneous nodal heat storage and supply rates.

During intervals in which the thermostat is not activated, Program MAIN calls the dynamic simulation subroutines which calculate the instantaneous fluid flows, temperatures and pressures throughout the distribution network. A full print-out of these TUS parameters and the consumer load distribution

is given at regular intervals as specified by the output print code.

A.3.2 Input Scaling (Subroutine CSCALE)

Originally conceived as a means for simplifying the input data requirements for a series of simulations investigating the effects upon system operation of varying only the community's thermal/electrical energy demand ratio, this subroutine is only partially completed. The use of an input mass flowrate scale factor (CSFAC) other than 1.0 will result in the specified initial flowrates being multiplied by that factor prior to their use in the TUS initialization calculations. Since neither the heat exchanger ratings nor the fluid temperatures are scaled internally, it is necessary to re-punch a significant portion of the input data when varying the demand ratio and, to avoid errors, it is recommended that the input mass flowrates be similarly repunched, with the value of CSFAC input as 1.0 until the internal scaling routine has been completed.

A.3.3 Consumer Heat Flow (Subroutine QLOAD)

Using a combination of American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) recommendations [4] and simplifications of procedures employed in the National Bureau of Standards Load Determination code (NBSLD) [5], Subroutine QLOAD calculates the hourly net

heat losses (gains) from each building type in the community based upon a steady-state energy flow analysis including the effects of heat conduction from the building to its surroundings, infiltration and ventilation air flows, solar radiation absorption and transmission, and internal heat generation from lights, appliances, people, etc. Due to the aggregate nature of the building units chosen to typify the large numbers of individual structures classified in each consumer grouping, emphasis in the development of Subroutine QLOAD has been placed upon the computation of building energy demand schedules reflecting the major components of the total building loads, but it is not as detailed nor as dynamically rigorous as the energy transfer function analyses performed by NBSLD. A major criterion in the derivation of the QLOAD demand models has been the minimization of complex building parameter specifications which would inordinately restrict the applicability of a given building unit as being "typical" of a fairly diverse mixture of structures. However, enough detail is included in the calculations that, if it is desired and is statistically valid, sensitivity analyses upon the building energy demands may be performed by varying certain design and construction specifications on a wall-by-wall basis.

Some basic assumptions made in the demand calculations are that all buildings specified are square and have symmet-

rical walls (i.e., that each of a given building's four walls is constructed identically to the others); that the roofs are flat (or that the input data describes a horizontal projection of the actual roof); that building occupancy, appliance and lighting usage, and forced-air ventilation requirements are closely correlated and may be scheduled according to the same building use function; and that a single temperature setting is to be maintained throughout all the rooms of each building type. All loads are calculated under instantaneous steady-state heat transfer conditions, and no consideration is made of such effects as the thermal inertia of the building walls or of energy transfers among regions within the building.

The first component of the building heat loads calculated in Subroutine QLOAD is that due to the combined effects of infiltration and ventilation air exchanges. For the purposes of this analysis, infiltration is defined as any air flow occurring as a result of wind and stack effect induced pressure differentials across cracks permeating the building's exterior surfaces. Ventilation air flows are those air exchanges scheduled by a building's occupants, either by the use of air circulation equipment or by opening windows. Infiltration is calculated in Subroutine QLOAD according to the crack factor method described in the User's Manual for NBSLD [6]. In general, the pressure loading on a given wall

consists of two components: that due to differences in the temperature and density of the air between the base and top of the wall (stack effect air convection) and that due to wind pressure on the wall's exterior surface. A simplified formula for determining the net stack effect pressure on a wall is given by Eq. (A.1).

$$PC = 5.3508 BH \left(\frac{1}{TOAB} - \frac{1}{TIAB} \right) \quad (A.1)$$

The conversion factor of 5.3508 includes the dimensional conversion factor of 7.644 (in. H₂O-°K/ft) multiplied by 0.7, since, according to ASHRAE, the net effects of a distributed stack effect pressure loading may be approximated by a single load concentrated at 70% of the building's height [4]. The theoretical direct normal wind-induced pressure loading on a wall is given by Eq. (A.2),

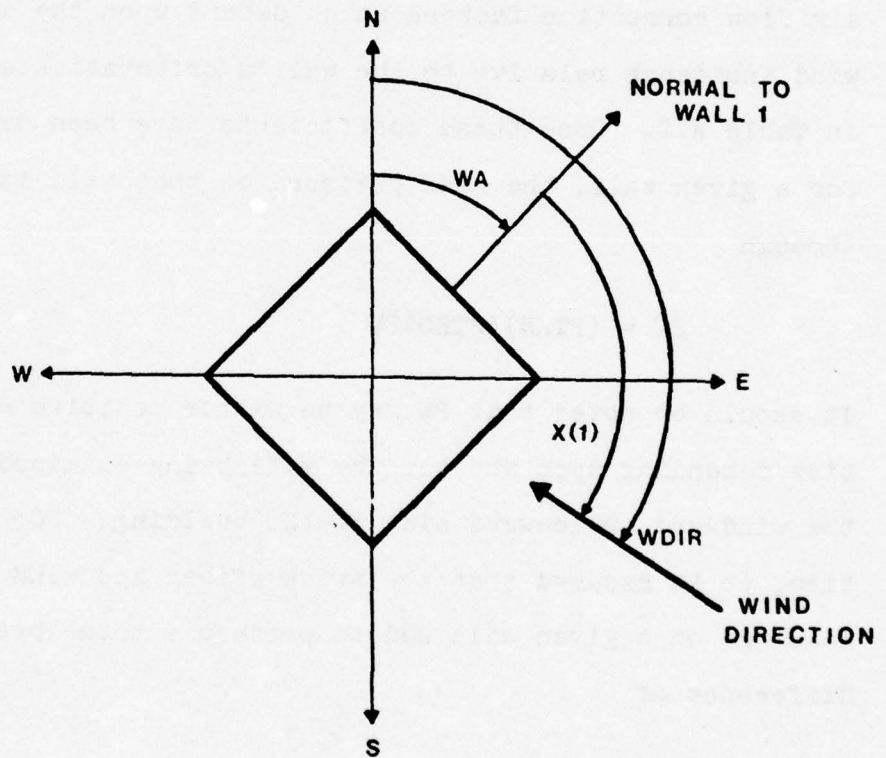
$$PV = 0.000482(WV)^2 \quad (A.2)$$

where the multiplier of 0.000482 converts (mph)² to a pressure difference in inches of water, relative to normal atmospheric pressure. However, since the ideal conditions under which this theoretical loading is derived are seldom observed in practice, the pressure computed in Eq. (A.2) must be scaled to account for the actual building orientation and for empirically-determined wall surface pressure reduction effects [6]. Figure A.5 illustrates the definition of the relative

29.

Figure A.5

Definition of Wall Normal and Wind Incidence
Directions Relative to North



wind incidence and wall normal directions as they are used in Subroutine QLOAD. Walls are numbered clockwise from the North, with #1 being the reference wall for normal angle WA. Because the air flow will, in general, be neither normal nor parallel to a given wall, the normal pressure term computed in Eq. (A.2) must be multiplied by normal and oblique air flow correction factors which depend upon the angle of wind incidence relative to the wall's orientation as shown in Table A.2. Once these coefficients have been determined for a given wall, the wind pressure on that wall is computed through

$$PW = (PTKN)(PTKO)PV . \quad (A.3)$$

It should be noted that PW may be either positive or negative depending upon whether the wall being examined is on the windward or leeward side of the building. For conservatism, it is assumed that the stack effect and wind pressure loadings on a given wall add to produce a total pressure difference of

$$PT = PW + PC . \quad (A.4)$$

Once the total pressure difference across a crack is known, the volumetric air flowrate through the crack may be determined through the use of infiltration coefficients based upon ASHRAE tabulated air flow measurements [6]. Table A.3

TABLE A.2

NORMAL AND OBLIQUE AIR FLOW WIND PRESSURECORRECTION FACTORS

(from Ref. 6)

<u>Angle Between Wind Incidence Direction and Normal to Wall i</u>	<u>Correction Factor</u>	
	<u>Normal (PTKN)</u>	<u>Oblique (PTKO)</u>
$-45^\circ < x(i) < +45^\circ$	0.60	$\cos(x(i))$
$90^\circ < x(i) < 270^\circ$, or $-90^\circ < x(i) < -270^\circ$	-0.35	1.0
$45^\circ < x(i) < 90^\circ$, or $-45^\circ < x(i) < -90^\circ$	-0.70	$\cos(x(i))$

lists the air flow coefficients - determined for several types of cracks - which are used in the general infiltration formula

$$(LI)_i = (CL)_i (C_i) (PT)^{N_i} \quad (A.5)$$

In Subroutine QLOAD, infiltration air flowrates are computed in this manner on a wall-by-wall basis for cracks around doors, windows and in the structural walls, and the resulting components are summed to produce a net total infiltration air leakage for the building.

For many types of small buildings, such as single family homes, infiltration heat losses dominate those due to ventilation. However, for large commercial buildings, which are generally better constructed and are regulated by municipal building codes, ventilation is the dominant mode of air exchange. In Subroutine QLOAD, ventilation is scheduled according to each building's occupancy-related use factor as is shown in Eq. (A.6).

$$VLEAK = (BUF)(AINFL) \quad (A.6)$$

During every simulation time step, each building's infiltration and ventilation air flowrates are compared, and the larger is used to determine the building's instantaneous air exchange heat loss rate through

TABLE A.3
INFILTRATION AIR FLOW COEFFICIENTS
 (from Ref. 6)

	<u>C</u>	<u>N</u>
1. Double-hung wooden windows(locked)*		
non-weatherstripped loose fit	6	0.66
average fit	2	0.66
weatherstripped loose fit	2	0.66
average fit	1	0.66
2. Window frames*		
masonry frame with no caulking	1.2	0.66
masonry frame with caulking	0.2	0.66
wooden frame	1	0.66
3. Swinging doors*		
1/2" crack	160	0.5
1/4" crack	80	0.5
1/8" crack	40	0.5
4. Walls**		
8" plain brick	1	0.8
8" brick and plaster	0.01	0.8
13" plain brick	0.8	0.8
13" brick and plaster	0.004	0.7
13" brick, furring, lath and plaster	0.03	0.9
frame wall, lath and plaster	0.01	0.55
24" shingles on 1x6 boards on	9	0.66
14" centers		
16" shingles on 1x4 boards on	5	0.66
5" centers		
24" shingles on shiplap	3.6	0.7
16" shingles on shiplap	1.2	0.66

*Values of C listed for these openings are per linear foot of crack length.

**Values of C listed for the walls are per square foot of surface area.

$$Q_{LEAK} = (\rho_a C_{pa})(A_{LEAK})(T_{SB} - T_{AIR}) . \quad (A.7)$$

(The infiltration and ventilation flowrates are not summed, since it is assumed that, to some extent, one substitutes for the other in determining overall building comfort levels. A comparison between the two components allows, for example, ventilation to be turned off at night, with infiltration remaining high due to high winds).

In order to determine the effects of solar radiation absorption and transmission upon a building's total space conditioning energy demands, it is necessary to first determine the direction and intensity of the sun's rays striking the four walls and roof of the building. In Subroutine QLOAD, the direction cosines of a direct solar beam are referred to the normal to a horizontal surface as is shown in Fig. A.6. At any time during the day, the solar hour angle relative to the horizontal surface normal is

$$H = 15 (TIME - 12) . \quad (A.8)$$

If

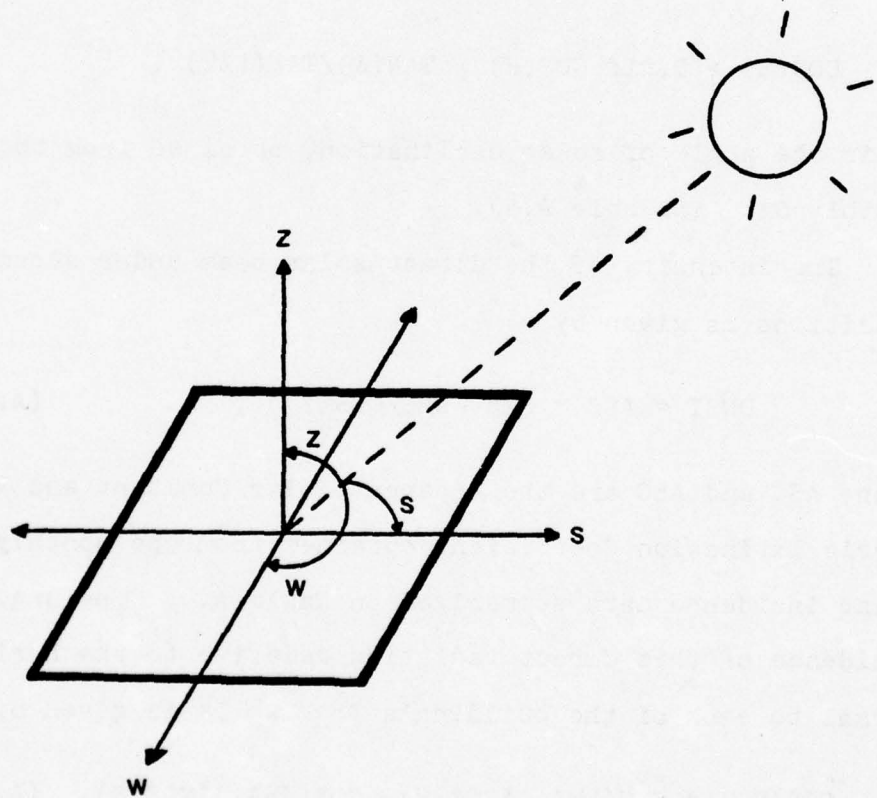
$$|\cos(H)| > |-\tan(LAT) * \tan(\delta)|$$

the sun has risen above the horizon, and the direct solar beam direction cosines are defined by

35.

Figure A.6

Definition of Solar Beam Direction Cosines



$$\cos(Z) = \sin(\text{LAT}) * \sin(\delta) + \cos(\text{LAT}) * \cos(\delta) * \cos(H), \quad (\text{A.9a})$$

$$\cos(W) = \cos(\delta) * \sin(H), \text{ and} \quad (\text{A.9b})$$

$$\cos(S) = (1 - \cos^2(Z) - \cos^2(W))^{0.5}, \quad (\text{A.9c})$$

where

$$\cos(S) > 0, \text{ if } \cos(H) > \tan(\delta) / \tan(\text{LAT}).$$

(δ is the angle of solar declination, obtained from the monthly data in Table A.4).

The intensity of the direct solar beam under cloudless conditions is given by

$$\text{DNSI} = \text{ASC} * \exp(-\text{AEC} / \cos(Z)), \quad (\text{A.10})$$

where ASC and AEC are the Apparent Solar Constant and Atmospheric Extinction Coefficient obtained from the monthly solar incidence data summarized in Table A.4. The angle of incidence of this direct radiation relative to the horizontal normal to each of the building's four walls is given by

$$\cos(\theta_i) = \sin(\text{SWA}_i) * \cos(W) + \cos(\text{SWA}_i) * \cos(S), \quad (\text{A.11a})$$

where SWA is the orientation of the wall being studied relative to South (i.e., angle WA as defined in Fig. A.5, minus 180 degrees). The cosine of the angle of direct solar incidence upon the building's (flat) roof is

TABLE A.4
SOLAR INCIDENCE DATA⁽¹⁾
(from Ref. 7)

<u>Date</u>	<u>Apparent Solar Constant (BTU/hr-ft²)</u>	<u>Solar Declination (Degrees)</u>	<u>Atmospheric Extinction Coefficient</u>	<u>Sky Diffuse Factor</u>
Jan. 21	390	-20.0	0.142	0.058
Feb. 21	385	-10.8	0.144	0.060
Mar. 21	376	0.0	0.156	0.071
Apr. 21	360	11.6	0.180	0.097
May 21	350	20.0	0.196	0.121
June 21	345	23.45	0.205	0.134
July 21	344	20.6	0.207	0.136
Aug. 21	351	12.3	0.201	0.122
Sept. 21	365	0.0	0.177	0.092
Oct. 21	378	-10.5	0.160	0.073
Nov. 21	387	-19.8	0.149	0.063
Dec. 21	391	-23.45	0.142	0.057

(1) Data values listed are for the Northern Hemisphere; for Southern Hemisphere locations, the values of AEC and SDF should be shifted by six months.

$$\cos(\theta_p) = \cos(Z) . \quad (A.11b)$$

The intensity of the direct solar radiation striking each of these surfaces is determined by the intensity of the direct normal solar radiation at the computed incidence angle, modified by any existing surface shading.

$$DSI_i = FWLIT_i * DNSI * \cos(\theta_i) \quad (A.12)$$

Diffuse solar radiation striking the building's surfaces under cloudless conditions obtains from diffusion of the direct solar beam as it passes through the atmosphere,

$$I_{da} = DNSI * SDF , \quad (A.13a)$$

where the Sky Diffuse Factor SDF is obtained from Table A.4, and from radiation reflected from the ground,

$$I_{dg} = \rho_g (I_{da} + DNSI * \cos(Z)) , \quad (A.13b)$$

where for most surfaces the ground reflectivity $\rho_g \approx 0.2$. For a horizontal surface, the incident diffuse solar radiation intensity is I_{da} . For a vertical surface, a scattering factor must be computed to yield an effective angle of incidence for the radiation [8].

$$Y_i = 0.55 + 0.437 \cos(\theta_i) + 0.313 \cos^2(\theta_i), (A.14a)$$

or, if $\cos(\theta_i) \leq -0.2$,

$$Y_1 = 0.45. \quad (A.14b)$$

The total intensity of the diffuse radiation striking each of the building's walls is thus

$$DFSI_1 = (I_{da} * Y_1 + 0.5 I_{dg}) * FWLIT_1, \quad (A.15a)$$

and of that striking the roof,

$$DFSIR = I_{da} * FWLIT_r. \quad (A.15b)$$

Heat gained by a building from the sun may be attributed to two effects: the internal absorption of radiation transmitted through windows, and the absorption of radiation by the walls and roof. The solar heat gain through a building's windows is obtained through the calculation of a window solar heat gain factor based upon polynomial expansions of the window's solar transmissivity and absorptivity [9,10].

$$\begin{aligned} SHGF_1 = & DSI_1 * F_{11} + 2 * DFSI_1 * F_{12} + 0.267 (DSI_1 * F_{13} \\ & + 2 * DFSI_1 * F_{14}) \end{aligned} \quad (A.16)$$

The factors F_{11} - F_{14} are the transmission and absorption coefficients obtained from the expansions for 1/8" thick single plate glass:

$$\text{Direct transmission } F_{i1} = \sum_{j=0}^5 T_j \cos^j(\theta_i), \quad (\text{A.17a})$$

$$\text{Diffuse transmission } F_{i2} = \sum_{j=0}^5 T_j / (j+2), \quad (\text{A.17b})$$

$$\text{Direct absorption } F_{i3} = \sum_{j=0}^5 A_j \cos^j(\theta_i), \text{ and } (\text{A.17c})$$

$$\text{Diffuse absorption } F_{i4} = \sum_{j=0}^5 A_j / (j+2), \quad (\text{A.17d})$$

where the polynomial coefficients A_j and T_j are given in Table A.5. The factor of 0.267 multiplying the radiation absorption term in Eq. (A.16) arises from a comparison of typical inner and outer glass surface thermal resistances, and it is used to approximate the ratio of inward to outward heat flows due to radiation absorbed by the glass [10]. The rate of solar heat gain through the windows in wall 1 is given by the product of the solar heat gain factor for those windows, the window area in that wall (assumed to be 1/4 of the total building window area due to the symmetrical wall assumption), and an internal window shading coefficient depending upon such factors as double glazing, tinted glass, and the use of drapes, blinds, etc.

$$QWDSG_i = AWD_i * SHGF_i * WDSC \quad (\text{A.18})$$

Representative shading coefficients are listed in Table A.6

41.

TABLE A.5
POLYNOMIAL COEFFICIENTS USED IN CALCULATION OF
WINDOW SOLAR HEAT GAIN FACTORS
(from Ref. 9)

Single Glazing, 1/8" sheet

<u>j</u>	<u>A_j</u>	<u>T_j</u>
0	0.01154	-0.00885
1	0.77674	2.71235
2	-3.94657	-0.62062
3	8.57881	-7.07329
4	-8.38135	9.75995
5	3.01188	-3.89922

TABLE A.6
WINDOW SHADING COEFFICIENTS

TYPE OF GLASS	<u>WDSC</u>
Regular sheet: $3/32 - 1/4$ $1/4 - 1/2$	0.95 - 1.00 0.88 - 0.95
Grey sheet: $1/8$ $1/4$	0.78 - 0.80 0.86 - 0.88
Heat-absorbing plate: $1/4$ $1/2$	0.70 - 0.74 0.50 - 0.57
TYPE OF SHADING	
Venetian blinds: medium light	0.42 - 0.64 0.40 - 0.55
Roller shade: dark opaque white opaque translucent	0.36 - 0.59 0.25 - 0.28 0.31 - 0.39
Draperies	0.35 - 0.80
Louvered sun screens	0.15 - 0.40

for a variety of common glass types and room decors; more extensive tabulations are found in ASHRAE [4], pp. 402-408. The individual-wall solar heat gains are added to produce a total window solar heat gain for the building.

The effects of solar radiation absorption and reflection at the building's wall and roof surfaces may be approximated by the use of a surface "sol-air" temperature in the building component's steady-state heat conduction equation [4]. The sol-air temperature for a surface is given by

$$TSA_1 = TAIR + SAB_1 * (DSI_1 + DFSI_1) * HO_1, \quad (A.19)$$

where SAB_1 is the solar absorptivity of the surface and HO_1 is the surface convection heat transfer coefficient. Table A.7 lists several absorptivities for typical building materials, a more extensive summary of which is given in Table C6 of NBSLD [5]. The convection heat transfer coefficient for a surface depends primarily upon the velocity of the wind striking the surface and the roughness of the surface material:

$$HO_1 = \frac{1}{C_{a1} * (WV)^2 + C_{b1} * (WV) + C_{c1}}, \quad (A.20)$$

where the coefficients in this formula are functions of the surface material type as given in Table A.8. To determine the net heat conduction rate out of the building through its walls and roof, including the effects of solar heating, the

TABLE A.7
SOLAR ABSORPTIVITIES OF TYPICAL BUILDING MATERIALS
(from Ref. 5)

<u>MATERIAL</u>	<u>SAB</u>
Brick: red common	0.68
light buff	0.36
white glazed	0.26
Tiles: dark clay	0.82
red	0.67
brown concrete	0.85
Roofing: asphalt	0.91
bituminous felt	0.89
black matte sheet	0.97
blue slate	0.86
Wood	0.78
Marble	0.58
White plaster	0.29

TABLE A.8
COEFFICIENTS USED IN CALCULATING SURFACE
CONVECTION HEAT TRANSFER COEFFICIENTS
(from Ref. 5)

<u>MATERIAL</u>	<u>C_a</u>	<u>C_b</u>	<u>C_c</u>
Stucco	0.0	0.464	2.04
Brick, rough plaster	0.001	0.320	2.20
Concrete	0.0	0.330	1.90
Clear pine	-0.002	0.315	1.45
Smooth plaster	0.0	0.244	1.80
Glass, white paint on pine	-0.00125	0.262	1.45

wall and roof material heat transfer coefficients are calculated by

$$AUW_i = \frac{AW_i}{RTW_i + WHO_i} + \frac{AWD_i}{RTWD_i} \quad (A.21a)$$

and

$$AUR = \frac{AR}{RTR + RHO} \quad (A.21b)$$

The total heat conduction rate to the ambient air is obtained by adding the components for the four walls and the roof:

$$QCOND_a = \sum_{i=1}^4 AUW_i * (TSB - TSA_i) + AUR * (TSB - TSAR) \quad (A.22)$$

The heat conducted from the building to the earth is

$$QCOND_g = AUG * (TSB - \frac{TSB + TAMB}{2}) \quad (A.23)$$

where the average between the desired building temperature and the ambient earth temperature is used to account for heating of the soil in direct contact with the building. The total heat conduction rate from the building is given by the sum of this ground loss and the heat lost to the air.

Energy flows due to the production of heat within a building are lumped into a single term accounting for lighting, appliances, people, etc., which are scheduled according to the building's occupancy-related use factor as

$$QLIG = (BUF)(POL) . \quad (A.24)$$

Finally, the net total heat loss from a building due to these component energy flows is given by

$$QL = QCOND + QLEAK - QWDSG - QLIG . \quad (A.25)$$

It should be noted that, as defined here, a positive heat flow indicates a net heat loss from the building to its surroundings.

A.3.4 Building Load Distribution (Subroutine DLOAD)

In Subroutine DLOAD, the building heat losses (gains) computed in Subroutine QLOAD are applied to the TUS load center heat exchangers and the electrical supply network according to the specified distributions of buildings and end-use equipment in the community being studied. When translating the heat losses to utility system demands, care is taken to include the effects of variations in the end-use equipment coefficients of performance with changes in the building room and ambient air temperatures. A printout of the community load distribution is provided at regular intervals during the simulation as specified by the user-defined output code. Since the demands in Subroutine QLOAD are calculated only at hourly intervals, Subroutine DLOAD computes hourly load distributions which are used as inputs to linear

interpolation equations in Program MAIN to produce the continuous load schedules required for the dynamic system analysis. (Instantaneous distributions may be calculated by Subroutine DLOAD at any time during the simulation as called for by the output schedule, but these instantaneous values are based upon linear interpolations between previously computed hourly data points.)

Associated with each load center heat exchanger in the TUS are a set of six numbers for each building type in the community: the number of units of that building type served by the heat exchanger, and the numbers of compressive air conditioners, absorptive air conditioners, heat pumps, hot water space heating units and resistance heaters within these buildings. (e.g., load center heat exchanger #5 might serve 20 units of building type 1, of which 11 have absorptive air conditioners, 9 have compressive air conditioners, 7 have heat pumps, 13 have hot water heat, and 0 have resistance heaters.) At each hourly interval, all the specified building types are examined at each heat exchanger to determine how many, if any, of each type have equipment connected to the TUS at that point. The total space-conditioning heat loss from these buildings is then calculated by

$$Q_i^k = NU_i^k * QL_i, \quad (A.26)$$

where QL_i is the net heat loss (gain) from one unit of build-

ing type i computed in Subroutine QLOAD (or is an off-hour load obtained through linear interpolation between two hourly values), and the superscript indicates the calculation is performed for buildings served by heat exchanger k . Domestic hot water energy demands are also computed in Subroutine DLOAD for each of the building types according to the user-specified water consumption schedules through

$$QDHW_i^k = NU_i^k * WUF_i * DHW_i . \quad (A.27)$$

(The service hot water demands are computed here rather than in Subroutine QLOAD as a matter of convenience. They are added to the net space conditioning loads and cannot be used to offset building heat losses computed in QLOAD).

After computing the aggregate space conditioning demand for a given building type at a given load center heat exchanger, Subroutine DLOAD determines whether this demand is due to space heating or cooling and applies it to the appropriate end-use equipment for that building type. If the load is due to space cooling, it may be supplied by either electric compression air conditioners or by hot water (or low pressure steam) liquid absorption chillers, if the outside air temperature is greater than that desired within the building. If the outside air temperature is lower than the desired room temperature (the cooling load resulting from internal heat generation or solar heating), it is assumed that venti-

lation will be increased to cool the building, and no loads are applied to either type of air conditioning equipment. (This criterion may be employed by the user to insure certain buildings of not being cooled by simply specifying their desired temperatures to vary exactly with the known ambient air temperature schedule). If the outside air temperature exceeds the room temperature, the nominal coefficient of performance of each air conditioning unit (defined at an air temperature of 90 °F and a room temperature of 75 °F) is scaled according to the theoretical Carnot cycle performance for a refrigerator:

$$\text{COP}' = \text{COP}_0 \left(\frac{0.028037}{\frac{\text{TOAB}}{\text{TIAB}} - 1} \right), \quad (\text{A.28})$$

where the 0.028037 factor is defined by the ideal Carnot heat engine efficiency at the specification temperatures:

$$\frac{1}{\text{COP}_s} = \frac{\text{TOAB}}{\text{TIAB}} - 1 = \frac{90+460}{75+460} - 1 = 0.028037.$$

It should be noted that COP_0 , the nominal coefficient of performance for the given air conditioning unit at $\text{TOAB} = 550$ °K and $\text{TIAB} = 535$ °K, should not be the theoretical Carnot cycle COP under those conditions, but should reflect the manufacturer's specifications for the actual units installed in the system. The Carnot cycle efficiency is merely

used by Subroutine DLOAD as an approximate indicator of the relative behavior of the actual COP as the room and air temperatures vary over time. Applying the COP' computed for each of the air conditioning units to the aggregate loads to be met by those units, the total energy demands for space cooling are determined by

$$\text{electric compression: } Q_{\text{CMP}}^k_i = F_{\text{ei}}^k * Q_i^k / \text{BCMP}, \text{ and (A.29a)}$$

$$\text{thermal absorption: } Q_{\text{ABS}}^k_i = (1 - F_{\text{ei}}^k) * Q_i^k / \text{BABS}, \text{ (A.29b)}$$

where F_{ei}^k is the ratio of electrically supplied space cooling to the total space cooling loads for building type i at heat exchanger k :

$$F_{\text{ei}}^k = \frac{\text{NCMP}_i^k}{\text{NCMP}_i^k + \text{NABS}_i^k} \quad . \quad (\text{A.30})$$

(BCMP and BABS are the scaled COP's for the compressive and absorptive air conditioning units, respectively).

Space heating demands are treated analogously to cooling loads. If the outside air temperature exceeds the desired room temperature for a given building type, no space heating demand for that building type is applied to the energy distribution networks. Heat pump COP's are defined at conditions of 32 °F air temperature and 68 °F room temperature, with the ideal Carnot cycle efficiency factor being

$$\frac{1}{\text{COP}_s} = 1 - \frac{\text{TOAB}}{\text{TIAB}} = 1 - \frac{32+460}{58+460} = 0.068182.$$

Variations in either temperature from these set-point conditions cause the COP to be modified according to

$$\text{COP}' = \text{COP}_o \left(\frac{0.068182}{1 - \frac{\text{TOAB}}{\text{TIAB}}} \right). \quad (\text{A.31})$$

The space heating demands may be supplied by heat pumps, hot water heat, or by electric resistance heaters, with the loads applied to the utility systems being determined by

$$\text{electric heat pumps: } \text{QHPM}_i^k = F_{\text{hpi}}^k * Q_i^k / \text{BHPM}, \quad (\text{A.32a})$$

$$\text{hot water: } \text{QHWS}_i^k = F_{\text{hwi}}^k * Q_i^k / \text{EHWS}, \text{ and } (\text{A.32b})$$

$$\text{resistance: } \text{QRES}_i^k = F_{\text{ri}}^k * Q_i^k / \text{ERES}, \quad (\text{A.32c})$$

where the load fractions for building type i at heat exchanger k are defined, in general, by

$$F_{xi}^k = \frac{N_{xi}^k}{\text{NHPM}_i^k + \text{NHWS}_i^k + \text{NRES}_i^k}. \quad (\text{A.33})$$

All heat pumps in the system are assumed to be provided with auxiliary resistance heating coils. At each hourly interval, the scaled heat pump COP (BHPM) is compared with the COP of a resistance heating unit (ERES, assumed to be 1.0), and if

the heat pump COP is less than that of the resistance heater, all heat pump loads are transferred to their resistance back-up units.

Domestic hot water demands are assumed to be supplied through the use of hot water heat exchangers in buildings supplied with hot water heat from the TUS, or through the use of electric hot water heaters in buildings containing heat pumps or resistance space heaters. The service hot water demands represent an additional heating load which may be conceptually applied to the same type of equipment as that supplying the space heating requirements. Therefore, for buildings with domestic hot water loads, the equipment energy demands computed on Eqs. (A.32b,c) are modified to yield

$$\begin{aligned} \text{hot water: } QHWS_1^k &= QHWS_1^k(\text{space heating}) + \\ &F_{hwi}^k * QDHW_1^k / EHWS, \text{ and} \end{aligned} \quad (A.34a)$$

$$\begin{aligned} \text{resistance: } QRES_1^k &= QRES_1^k(\text{space heating}) + \\ &(F_{hpi}^k + F_{ri}^k) * QDHW_1^k / ERES. \end{aligned} \quad (A.34b)$$

This load analysis is performed for every building type at each load center heat exchanger for each hour of the simulation period. The resulting thermal demands define the distributed hourly load schedules to be met by the TUS, and the electrical demands are aggregated to form one component

of the community's electrical load schedule. In addition to the buildings served by the TUS and distributed among its load center heat exchangers, there may be several buildings in the community which are not provided with HTW service but which are supplied with electricity from the TES power plant. For the purposes of calculating these "external system" loads in Subroutine DLOAD, all of the units of a given building type not served by the TUS are aggregated into a single grouping, independently of their actual geographical locations within the community. (Since no detailed analysis is performed on the electrical distribution network, there is no need to specify transmission distances to these consumers.) Proceeding analogously to the computations described above for those buildings connected to the TUS, the external system energy demands are calculated as follows.

- 1) Total space conditioning demand for all units of building type i not served by the TUS:

$$QEXT_i = NUEX_i * QL_i , \quad (A.35)$$

where QL_i is the hourly demand computed in Subroutine QLOAD, or is an interpolated load if the demands are being computed during one of the simulation hours.

- 2) Total domestic hot water energy demand for all units of building type i not served by the TUS:

$$QDEXT_i = NUEX_i * WUF_i * DHW_i . \quad (A.36)$$

- 3) Total compressive air conditioning energy demand for all units of building type i not served by the TUS:

$$QCEXT_i = QEXT_i / BCMP , \quad (A.37)$$

where $QCEXT_i$ is defined for $TOAB > TIAB_i$, and $BCMP$ is the air conditioner COP scaled according to the relation in Eq. (A.28). It should be noted that all buildings in the external system requiring cooling are assumed to be served by compressive air conditioning units. Those few building not served by the TUS using absorption chillers will also have in-house fossil-fired furnaces to supply their heating loads - due to the high cost of installing and operating dual heating and cooling systems - and, for the purposes of this TES analysis, will have no effect upon the overall energy system design.

- 4) Total heat pump energy demand for all units of building type i not served by the TUS:

$$QHEXT_i = FHPEX_i * QEXT_i / BHMP , \quad (A.38)$$

where all space heating demands are defined only for $TOAB < TIAB_i$, and $QHEXT_i$ is zero if the scaled COP ($BHMP$, from Eq. (A.31)) is less than 1.0.

- 5) Total resistance heating energy demand for all units of building type i not served by the TUS:

$$QREXT_1 = FREXT_1 * QEXT_1 / ERES + \\ (FREXT_1 + FHPEX_1) * QDEXT_1 / ERES , \quad (A.39)$$

and $QREXT_1$ includes the heat pump space heating demands if the heat pump COP is less than ERES.

- 6) Total hot water energy demand for all units of building type 1 not served by the TUS:

$$QHWEX_1 = (1 - FHPEX_1 - FREXT_1) * (QEXT_1 + QDEXT_1) / EHWS . \\ (A.40)$$

This demand is assumed to be supplied by in-house fossil fuel furnaces and is not applied to the TES analysis (other than as an entry in the external system building load distribution summary). Although, as is described above, it is assumed that any external system buildings containing absorptive air conditioning units will also contain fossil-fired furnaces and will not affect the TES analysis, present construction practices demonstrate that it is very likely that a building having an in-house fossil furnace will also have compressive air conditioning. These buildings will affect the total electrical loads to be met by the TES power plant, and they must therefore be included in this demand analysis.

In order to compute the total system hourly electrical energy demands, the electrical demands computed in Eqs. (A.29a), (A.32a), and (A.34b), summed over all the building types and all the load center heat exchangers, are added to the total external system electrical demands. These hourly space conditioning and domestic hot water loads are transmitted to Program MAIN, where they are added to the aggregate non-space-conditioning electrical load for the community to produce the hourly total electrical demands to be met by the TES power plant electrical output.

A.3.5 Steady-State System (Subroutine STDY)

Subroutine STDY is an iterative steady-state heat flow subprogram which establishes the nodal fluid flowrates and temperatures throughout the TUS for given thermal load and supply conditions. The essence of the routine lies in a steady-state heat balance performed on each of the nodes which requires equality between the convective and conductive heat flows from the node. The further requirements of continuity of the temperature profiles and fluid flows across the boundaries between consecutive nodes within each loop serve to physically join the separate nodal parameters and to insure conservation of energy and momentum around the loops. The loop flows and temperatures resulting from the heat balance are adjusted iteratively until the system converges to the conditions satisfying both nodal and total system

energy balance.

The bases of the nodal heat balance calculation are the steady-state convection and conduction equations given by:

$$\text{convection: } \dot{Q} = \text{MASS} * \text{CAP} * (\text{TI} - \text{TO}) , \text{ and} \quad (\text{A.41})$$

$$\text{conduction: } \dot{Q} = \text{AUF} * \text{DTLM} . \quad (\text{A.42})$$

DTLM is the log-mean temperature difference between the fluid in the node and the fluid to which heat is being transferred and is expressed by:

$$\text{DTLM} = \frac{\text{TN} - \text{TD}}{\ln \left(\frac{\text{TN}}{\text{TD}} \right)} , \quad (\text{A.43})$$

where TN = temperature difference across the node inlet, and
TD = temperature difference across the node outlet.

For a length of pipe transferring heat to the earth,
Eq. (A.42) becomes:

$$\dot{Q} = (\text{AUF}) * \left[\frac{\text{TI} - \text{TO}}{\ln \left(\frac{\text{TI} - \text{TAMB}}{\text{TO} - \text{TAMB}} \right)} \right] \quad (\text{A.44})$$

since the earth temperature is assumed to be constant along the length of the pipe. Combining Eqs. (A.41) and (A.44) yields the following expressions for the nodal inlet and outlet fluid temperatures for a length of pipe:

$$T_I = T_O \exp [AUF / (MASS * CAP)] + T_{AMB} [1 - \exp [AUF / (MASS * CAP)]] , \quad (A.45a)$$

and

$$T_O = T_I \exp [-AUF / (MASS * CAP)] + T_{AMB} [1 - \exp [-AUF / (MASS * CAP)]] , \quad (A.45b)$$

All heat exchangers are assumed to be of the single-pass counterflow type*. Designating the node being analyzed as the "1" or "primary" side of the heat exchanger and the opposite node as the "2" or "secondary" side,** the conductive heat flow out of the primary side can be expressed by:
(see Fig. A.7 for reference)

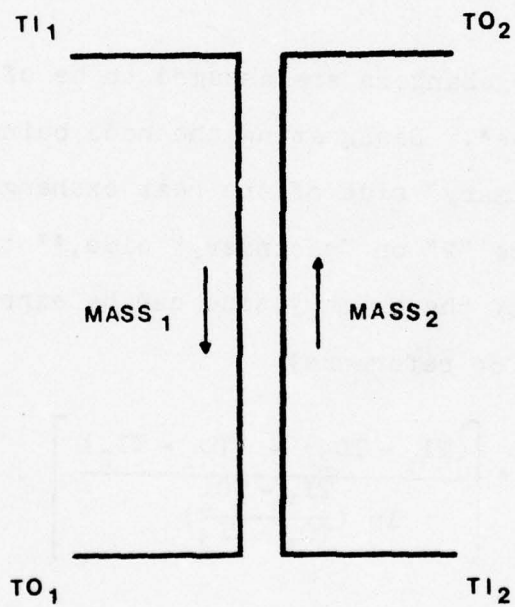
$$Q = (AUF) * \left[\frac{(T_{I1} - T_{O2}) - (T_{O1} - T_{I2})}{\ln \left(\frac{T_{I1} - T_{O2}}{T_{O1} - T_{I2}} \right)} \right] . \quad (A.46)$$

*If it is desired to use a different configuration in the actual TUS design, a conversion factor may be applied to the heat transfer coefficient of the actual heat exchanger to transform it to an equivalent counterflow heat exchanger for the purposes of this model. [11]

**In this context, "primary" and "secondary" are not necessarily synonymous with hot and cold. The analysis developed here is independent of the side of the heat exchanger being studied; if the "1" side is the cold side, the heat transfer out of the node will simply be negative.

Figure A.7

Counterflow Heat Exchanger Schematic



The steady-state convective heat transfer rates on both sides of this heat exchanger must be equal to the conductive heat flowrate between them and are given by:

$$\dot{Q} = \text{MASS}_1 * \text{CAP}_1 * (\text{TI}_1 - \text{TO}_1), \text{ and} \quad (\text{A.47a})$$

$$\dot{Q} = \text{MASS}_2 * \text{CAP}_2 * (\text{TO}_2 - \text{TI}_2) . \quad (\text{A.47b})$$

Combining Eqs. (A.46), (A.47a), and (A.47b) to eliminate TO_1 , the primary nodal inlet temperature is determined by the relation:

$$\text{TI}_1 = \frac{\left[\frac{\text{MASS}_2 * \text{CAP}_2}{\text{MASS}_1 * \text{CAP}_1} - 1 \right] (\text{TO}_2 - \text{TI}_2)}{1 - \exp \left[\text{AUF} \left(\frac{1}{\text{MASS}_2 * \text{CAP}_2} - \frac{1}{\text{MASS}_1 * \text{CAP}_1} \right) \right]} + \text{TO}_2 \quad (\text{A.48})$$

A closed solution for all the nodal fluid mass flowrates and temperatures can be obtained only when information is available regarding the total thermal demands at each load center heat exchanger and the TUS steady-state heat input. In practice, Subroutine STDY requires as input data the inlet and outlet temperatures and fluid flowrates on the consumer sides of all the load center heat exchangers, the primary HTW loop fluid flowrate, and the primary loop fluid supply temperature at the storage reservoir. (See Fig. A.2 for a schematic representation of the TUS.) Subroutines QLOAD and DLOAD determine the steady-state loads to be applied to each load center heat exchanger, and the required fluid flowrates

are calculated to supply these loads within the user-defined heat exchanger temperature limits. The primary loop steady-state energy supply data are specified by the user according to the desired system design. Estimates of the total loop fluid flowrate and of the load center heat exchanger parallel branch flow splits in each of the secondary distribution loops may also be supplied to Subroutine STDY by the user, and will speed the convergence of the iterative solutions if chosen properly.

The system calculations are divided into two sections corresponding to the two sets of heat exchangers at the secondary loop and consumer supplies. For each secondary loop, Subroutine STDY first calculates a load center heat exchanger supply header reference temperature through the use of Eq. (A.48), the computed load center heat exchanger consumer-side demand data, and an estimated value of the first secondary loop parallel branch mass flowrate. Since all the load center heat exchangers are supplied from a common point in the secondary loop, the inlet temperatures on their supply sides must all be equal to the calculated reference temperature. Therefore, trial inlet temperatures computed through Eq. (A.48) for each of the load center heat exchangers are compared with the reference, and the branch flowrates are adjusted until the calculated temperatures are within 0.001%

of the required value.* When the temperatures have converged, they are set exactly equal to the reference value to avoid instabilities in future iterations, and the nodal outlet temperatures are calculated by requiring equality between the convective heat flows on both sides of the heat exchangers. Upon completion of this iterative process for each of the load center heat exchangers served by the secondary loop, the parallel branch fluid flowrates are added to produce the total secondary loop flow, and the parallel nodal outlet temperatures are combined to yield a mass-flow-averaged inlet temperature to the secondary loop return pipe. The outlet temperature on the secondary loop side of the secondary supply heat exchanger is then calculated from Eq.(A.45a) using the parallel branch supply header reference temperature as T_0 ; the inlet temperature to the secondary supply heat exchanger is calculated using Eq. (A.45b) and the mass-flow-averaged return header temperature.

The inlet temperature on the primary loop side of the first secondary supply heat exchanger is computed by using in Eq. (A.45b) the specified loop fluid flowrate and the HTW supply temperature at the storage reservoir. Since the

*Due to round-off errors in the calculations, the two values will never become exactly equal; a higher degree of precision than the 0.001% chosen leads to much longer times for final system convergence.

primary HTW loop fluid flowrate and supply temperature are fixed by the system design, this inlet temperature is constant and defines the HTW reference temperature for the first secondary supply heat exchanger. The loop fluid flowrate and the inlet and outlet temperatures on the secondary side of the heat exchanger calculated in the iterative analysis of the load center heat exchangers are then used in Eq. (A.48) to yield a trial primary-side supply temperature which is compared with the reference. If the difference between these values is greater than the 0.001% convergence limit, the secondary loop fluid flowrate is adjusted to decrease the error. The new secondary loop flow is split among the parallel load center heat exchangers in proportion to their loads, a new supply header reference temperature is calculated, and the load center heat exchanger iteration process is begun again.

This double iteration procedure continues until all the calculated temperatures for the first secondary distribution loop fall within the required convergence limits. The outlet temperature on the primary loop side of the secondary supply heat exchanger is then set by requiring the specified primary loop fluid mass flowrate to supply the total heat load, including losses, of the secondary loop being examined. A reference HTW inlet temperature for the next secondary supply heat exchanger is calculated using Eq. (A.45b) and the first heat

exchanger outlet temperature, and the entire loop iteration procedure is started for the next secondary distribution loop. When all the loops have converged, the steady-state heat flows across each of the heat exchangers are calculated, and the nodal fluid mass flowrates and temperature data are printed out in a TUS steady-state design summary.

A.3.6 Initialization (Subroutine SET)

Subroutine SET is an intermediate program flow control subroutine which is called to control the building load analysis section of TDIST, to initialize the dynamic system simulation parameters to the converged steady-state conditions computed in Subroutine STDY, or to control the program flow when the Program MAIN thermostat model requires adjustment of the loop fluid flowrates.

During system initialization or steady-state design analyses (KODE = 0), Subroutine SET assumes control from Program MAIN and causes the hourly (or single time instant) building energy demands and the resulting TUS load distributions to be computed by Subroutines QLOAD and DLOAD. If only an analysis of the building loads is desired (IDES = 1), Subroutine SET causes the building energy demand schedules and the desired load distribution to be printed out and then returns control to Program MAIN, from whence the design run is terminated.

If it is desired to use the loads computed at the beginning hour of the simulation period as input data to the steady-state TUS calculations performed in Subroutine STDY (IDES = 0), Subroutine SET uses the load distribution from Subroutine DLOAD and the user-specified load center heat exchanger supply and return temperatures to compute the fluid mass flowrates on the consumer sides of all the load center heat exchangers. To prevent destruction of the existing system temperature and flowrate data in the event of non-convergence in Subroutine STDY, a set of dummy flowrates and temperatures are initialized to the existing system conditions and are transmitted to Subroutine STDY as the input data required by the heat balance analyses. Upon return of the converged steady-state TUS parameters, Subroutine SET transmits the loop fluid flowrates to Subroutine PRESS, in which the loop fluid frictional pressure losses and required circulation pump pressure settings are computed. Initialization of the TUS nodes to the computed steady-state conditions begins with the resetting of the actual nodal temperatures and fluid mass flowrates to the values returned from Subroutine STDY. The temperature of the cold water section of the thermal energy storage reservoir (see Fig. A.4) is set equal to the fluid temperature at the outlet of the last pipe node in the primary HTW loop; the hot water section temperature is fixed at the desired system HTW supply tempera-

ture specified by the user, and the fluid mass flowrate on the TUS side of the power plant thermal energy supply heat exchanger is calculated so as to absorb the net rate of thermal energy production by the power plant after meeting the steady-state system electrical demands. (The interfacing heat exchanger between the power plant and the TUS is not modelled in detail by TDIST and is simply assumed to have an "extremely large" heat transfer coefficient. It is included as a separate item in the system energy flow analysis to emphasize its existence and to provide a mathematical means for transferring energy between two physically different fluid flowstreams). Following the computation of this TUS supply fluid flowrate, Subroutine PREC, which monitors the TUS supply heat exchanger to insure that the Second Law of Thermodynamics is always obeyed by its combined energy flows, is called to verify the validity of the system supply conditions. Subroutine SET then calculates measures of the energy stored in each of the reservoir sections, based upon their initial volumes and fluid temperatures. (In the present form of the code, these are not true measures of the actual BTUs of energy stored, since the computations are performed in degrees Fahrenheit, referred to 0 °F rather than 0 °K. As a result, the printout data summarizing the reservoir energy storage should only be used as an indicator of the relative supply/demand variations of the system over time.

Since the reservoir volume output data is a correct measure of the actual amount of water stored in each reservoir section at any given instant, this data may be used, if necessary, to calculate the true energy storage variations over time.) Steady-state TUS nodal temperature and mass flowrate data and the distribution of the steady-state building energy demands are printed out in the steady-state system summary. Finally, the pressure settings of all the loop circulation pumps are initialized to the steady-state loop fluid frictional losses, and program control is returned to Program MAIN for either the beginning of the dynamic simulation or for termination of the run if only the steady-state system analysis output is desired.

If Subroutine SET is called during the dynamic system analysis (KODE = 1), its function is to transfer the desired nodal fluid mass flowrates computed by the thermostat model in Program MAIN to Subroutine PRESS, where they are translated into a set of corresponding loop pressure losses. These pressures are then shuttled to Subroutine FLOWS, in which they determine the desired settings of the loop circulation pumps to compensate for the out-of-balance energy flows detected by the thermostat.

A.3.7 Fluid Flowrate (Subroutine FLOWS)

As was mentioned previously, the primary mechanism employed in the TUS model to adjust for changes in the system

loads and supply conditions is the variation of the loop fluid flowrates. Subroutine FLOWS contains the model for this flowrate adjustment mechanism and also serves as the calling routine for the dynamic energy balance and fluid pressure loss calculation subroutines. Since the consumer tertiary distribution piping is assumed to have negligible fluid and thermal inertia, the fluid flows in the consumer sides of the load center heat exchangers are allowed to vary instantaneously with the thermal demands. However, since the secondary distribution and primary HTW loops contain a considerable volume of fluid, circulation pump models are provided for each of these loops which determine their steady-state fluid flowrates and the rates of fluid acceleration during transients.

At the end of the initiating steady-state calculations, the fluid friction pressure losses corresponding to the converged flows are calculated for each of the loops (see Subroutine PRESS), and the pump pressures are set to maintain these flowrates. When the thermostat is activated, a set of desired fluid flowrates is calculated in Program MAIN by requiring instantaneous energy balance across each of the heat exchangers in the system. The circulation pump pressures corresponding to these desired flows are calculated in Subroutine PRESS and are supplied to Subroutine FLOWS, where they are adjusted to speed system response before being applied

to the actual pumps. If the thermal loads increase, setting the pump pressures to the values necessary merely to maintain the projected loop fluid flowrates will cause the fluids to accelerate relatively slowly and to asymptotically approach the desired conditions over a fairly long period of time. Since it is desired to have the system respond as quickly as possible to changes in the thermal demands, the fluid acceleration rates are increased by setting the actual pumps at pressures somewhat higher than the required steady-state values. The factor by which the pressures are adjusted is proportional to the difference between the existing and the required pressures and, therefore, varies with the magnitude of the change in the thermal demands. By adjusting the proportionality constant in this correction factor, it is possible to achieve any desired degree of load following in the system fluid flowrates. However, very short reaction times (i.e., nearly instantaneous adjustment of the flows to exactly match the load conditions) tend to cause instabilities in the system because the time increments over which they occur must be of finite size and the thermal inertia of the system does not allow instantaneous adjustment of the fluid temperatures. In the current model, the pump pressure adjustment equation used is:

$$PEX = PP + PSENS*(PP - PS) , \quad (A.49)$$

where PP is the desired pressure setting computed in Subroutine PRESS from the desired loop flowrates, PS is the existing pump pressure setting, and a value for the pump response sensitivity factor PSENS of 2.0 has been found to be capable of maintaining realistic pressure variations and system stability while allowing fairly rapid response to demand changes. When the fluids have accelerated to within 1% of their projected flowrates, the pump pressures (PEX) are reduced to their required values (PP) to prevent exceeding the projected conditions and possible instabilities in the resulting heat flows.

If the thermostat is not activated, Subroutine FLOWS controls the dynamic energy and momentum transfer calculations which yield the instantaneous fluid temperatures and flowrates throughout the TUS. In these dynamic calculations, it is assumed that system conditions remain constant during each time interval, and new values for the fluid temperatures, pressures and flowrates are calculated at the end of a time step, based upon the instantaneous system thermal energy supply and demand conditions, and upon the overall energy flows and fluid momentum transfers during the preceding interval. Since this is a step-wise approximation to the continuous variation of these parameters, it is important that the specified simulation time step size be small compared with the time constants of the externally-varying heat demand and thermal energy supply functions to maintain system

stability.

The instantaneous nodal fluid temperatures are determined in dynamic energy flow calculations in Subroutine ENRG, which is called from Subroutine FLOWS before any of the nodal fluid flowrates are changed. The existing fluid flows in the secondary distribution and primary HTW loops are then supplied to Subroutine PRESS, where the total fluid friction pressure losses, including the effects of flow regulation valves, are calculated for each of the loops. These pressure losses are returned to Subroutine FLOWS and are compared with the circulation pump pressure settings to determine the acceleration or deceleration of the fluid during the preceding time interval. The instantaneous loop flows at the end of the time step are obtained by adjusting the flowrates at the beginning of the interval according to the calculated acceleration rate through:

$$DM = MASS + DTIME * FCTR * (PEX - PP) , \quad (A.50)$$

where PP is used here as the instantaneous fluid friction pressure loss calculated in Subroutine PRESS for the beginning-of-interval fluid mass flowrate MASS, and

$$FCTR = \frac{\pi g_c (DIA)^2}{4 (LONG)} , \quad (A.51)$$

with $g_c = 4.147 \times 10^8$ lbm-ft/lbf-hr². The relative flows in the parallel branches of the secondary distribution loops are determined by the new total loop flowrates given by Eq. (A.50)

and the settings of the branch flow regulation valves, which divide the loop flows according to the individual load center heat exchanger thermal demands. The relative bypass and heat exchanger flowrates at each secondary supply heat exchanger in the primary HTW loop are similarly determined according to the thermal demands at those heat exchangers.

Subroutine FLOWS also performs the energy transfer calculations for the thermal energy storage reservoir. As was mentioned previously, the reservoir is modelled physically as two separate storage volumes in series with the primary loop supply and return nodes at the TUS supply heat exchanger (see Fig. A.2). The initial hot water storage section temperature is specified in the input data as the desired HTW supply temperature for the primary loop. Since large variations in the primary loop inlet temperature, coupled with the continuous variation of the fluid flowrate to compensate for load changes, tend to cause instabilities in the system heat flows during periods of peak or minimum demand, this temperature is held constant throughout the simulation. The cold water storage temperature is initialized to the primary loop steady-state fluid return temperature. The fluid flowrate between the two reservoir sections is then calculated by requiring equality between the convective heat transfer rates on both sides of the TUS supply heat exchanger. The energy transferred to the water in the heat exchanger from the

power plant coolant flow is equal to the difference between the constant power plant total thermal energy output and the instantaneous energy demand for electrical generation. Since the supply heat exchanger outlet temperature is constant and the inlet temperature varies relatively slowly - as determined by the variations in the primary loop return fluid temperature, buffered by the large volume of fluid in the cold water section of the reservoir - the fluid flowrate between the two reservoir sections effectively follows the system thermal energy supply. At the end of each simulation time step, the water volume in each of the storage sections is adjusted according to the net fluid transfer during the interval. (e.g., if the primary loop flowrate is greater than that in the supply heat exchanger, there will be a loss of fluid from the hot water section and an increase in the volume of the cold water section.) If either of the sections is emptied during a given time step, the primary loop fluid flowrate is constrained to be equal to the flowrate through the thermal energy supply heat exchanger to satisfy conservation of mass and momentum around the continuous piping loop. The energy contained in each of the reservoir sections varies with both the volume and the average temperature of the water being stored. At the end of each time step, this energy storage is adjusted by comparing the thermal energy flows into and out of the section during the

interval. (In this calculation, it is assumed that heat conduction losses from the reservoir will be small compared with the convective heat flows from the precooler and the primary loop, and conduction effects are ignored. It should also be noted that, in the present version of the code, these energy terms are only relative measures of the actual energy stored in each section, since they are computed relative to 0 °F rather than 0 °K. Since the volume terms depend only upon the mass flowrates into and out of each section, they are rigorously correct indicators of the actual reservoir behavior). Thus, during periods in which the power plant thermal energy supply exceeds the system demands, the volume of water in the hot water storage section increases. During periods of higher demand, this stored energy supplements the power plant supply, and the water volume decreases.

A.3.8 System Pressure Drops (Subroutine PRESS)

Subroutine PRESS calculates the total fluid friction pressure losses for the secondary distribution and primary HTW loops, sets the circulation pump pressures to compensate for these friction losses, and controls the flow regulation valves in the secondary loop parallel supply branches to divide the loop flows according to the relative load center heat exchanger thermal demands. The subroutine is called during the initial steady-state system calculations to establish the initial pump pressures and valve settings,

when the thermostat is activated to determine the desired pressures and flow splits for the projected system flow-rates, and at the end of each simulation time step to calculate the instantaneous fluid pressure losses in each loop. The basis of the nodal fluid friction pressure loss calculation is the Darcy formula [12]:

$$DP = F*(LONG/DIA)*\left(\frac{MASS^2}{2*G*RHO*NTB^2*AC^2}\right), \quad (A.52)$$

where the familiar form of the equation has been modified slightly by expressing the fluid velocity in terms of the mass flowrate (MASS), the flowchannel cross-section (AC), and the number of parallel flowchannels (NTB). The factor F is the Darcy-Weisbach friction factor

$$F = \frac{0.184}{RE^{0.2}}; \quad (A.53)$$

RE is the fluid Reynolds number

$$RE = \frac{4*MASS}{\pi*NTB*DIA*MU}, \quad (A.54)$$

with the fluid velocity again expressed in terms of the mass flowrate, and the conversion constant $G = 4.147 \times 10^8$ lbm-ft/lbm-hr².

In a simple series loop, such as the primary HTW loop, the total frictional pressure loss is simply the sum of the

nodal losses determined through Eq. (A.52). Since the circulation pump for the loop must compensate exactly for these losses in steady-state, the pump pressure necessary to maintain the given loop fluid flowrate is set equal to the calculated total loop frictional pressure loss.

In calculating the friction losses for a secondary distribution loop, consideration must be given to the fact that the total fluid flow is split among several parallel branches serving the load center heat exchangers. Since all the branches in a given loop have common supply and return headers, the fluid flowing through each branch must experience the same total pressure drop. The flow regulation valve model employed in Subroutine PRESS uses this fact to introduce external pressure losses into selected branches in order to maintain different flowrates in similar flowchannel geometries. The desired nodal fluid flowrates are supplied to Subroutine PRESS from either the steady-state system calculation (Subroutine STDY) or the thermostat-controlled system projection (Program MAIN). Since all the calculations which establish these flowrates are based upon instantaneous energy balances across each of the heat exchangers in the system, the flows are divided among the parallel branches according to the relative thermal loads which they must supply. In each secondary distribution loop, the nodal friction pressure losses are calculated through Eq. (A.52), and the largest

parallel branch pressure drop is taken as the reference for the remainder of the branches. It is assumed that the valve in this reference branch is fully open, and the valves in the remaining branches are set by adding a valve friction term to each nodal friction factor to make all the parallel branch pressure losses equal to the reference. This parallel branch pressure drop is then added to the series node frictional losses to determine the total fluid pressure drop for the loop and to establish the circulation pump pressure necessary to maintain the desired flowrates.

During normal simulation periods, the instantaneous flowrates determined in Subroutine FLOWS are applied to Subroutine PRESS, where the loop fluid friction pressure losses corresponding to these flows are calculated. These frictional losses are then compared with the loop circulation pump pressure settings to determine the rates of fluid acceleration or deceleration as indicated in the section describing Subroutine FLOWS. The parallel branch flow regulation valves are set at the beginning of the simulation and every time the thermostat is activated to adjust the pump pressures. During normal dynamic calculations, however, their settings (i.e., the added terms in the parallel branch friction factors) remain constant as determined by the desired flow conditions, while the fluid friction losses for each of the nodes change as the loop flowrate varies. The valves thus establish the

relative parallel branch fluid flow splits based upon the desired system energy supply conditions and maintain these flow ratios until they are reset by the thermostat. (No models of the bypass valves in the primary loop are contained in Subroutine PRESS, since those valves are set through the combined effects of the thermostat flow split calculations in Program MAIN and the pump pressure resetting section of Subroutine FLOWS.)

A.3.9 Dynamic Energy Balance (Subroutine ENRG)

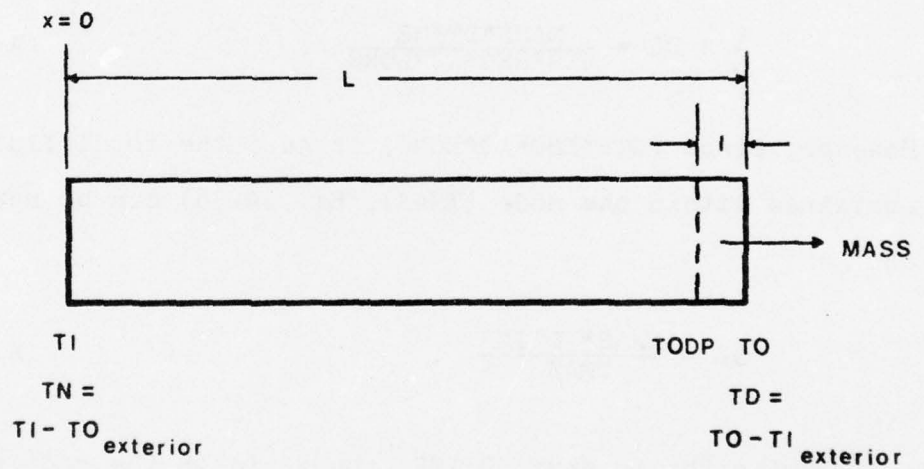
The dynamic energy flow calculations in Subroutine ENRG form the basis for the entire time-dependent TUS simulation since they determine the rate at which the distribution system follows the thermal energy supply and demand variations. The system fluid flowrates and nodal temperatures are assumed to be constant during each time interval according to the net imbalances in the heat flowrates and momentum transfers computed during the time step. Subroutine ENRG calculates the nodal inlet and outlet fluid temperatures throughout the TUS based upon an analysis of the nodal thermal energy flows during each time step. It is called from Subroutine FLOWS before any other system parameters are adjusted because, unless the thermostat is activated, the fluid flowrates vary independently of the fluid temperatures, while the energy flows and temperature variations depend strongly upon the fluid mass flowrates existing during the interval being

studied.

All energy transfer calculations in Subroutine ENRG have been derived under the assumption that the fluid in a given node travels only a relatively small fraction (e.g., 10-20%) of the length of the node during a single time step. (This criterion should be the dominant factor in the determination of the time step size specified for a given simulation.) During transients, the fluid inlet and outlet temperatures on either side of a heat exchanger may be perturbed so as to cause the temperature profiles to deviate from their steady-state shapes. In order to follow such perturbations along the entire length of a node, it is rigorously necessary to incorporate into the analysis an incremental flow indexing scheme which traces the time history of each element of fluid as it travels through each node in its respective piping loop. However, the effects of these continuous variations in the fluid temperature profiles may be modelled adequately for most situations encountered under normal system operating conditions by concentrating only upon the incremental energy flow variations at the inlet and outlet of each node. Subroutine ENRG therefore examines only the thermal energy transferred into and out of the incremental volume of fluid displaced during the time interval being studied. In Fig. A.8, it is assumed that a particle of fluid at $x = L - \Delta$ at the beginning of a time step ($t = 0$)

Figure A.8

Dynamic Nodal Energy Transfer Parameters



NTB channels/node,
single channel cross-section AC

flows to $x = L$ at the end of the interval ($t = \text{DTIME}$); thus

$$\ell = v * \text{DTIME} , \quad (\text{A.55})$$

where v is the nodal fluid velocity. Expressing the fluid velocity in terms of the nodal mass flowrate, the fraction of the length of the node travelled by the fluid in DTIME is

$$\frac{\ell}{L} \equiv \text{DL} = \frac{\text{MASS} * \text{DTIME}}{\text{NTB} * \text{RHO} * \text{AC} * \text{LONG}} . \quad (\text{A.56})$$

However, since $(\text{NTB} * \text{RHO} * \text{AC} * \text{LONG})$ is just the total fluid mass contained within the node (TMAS), Eq. (A.56) can be rewritten as

$$\text{DL} = \frac{\text{MASS} * \text{DTIME}}{\text{TMAS}} . \quad (\text{A.57})$$

During the interval DTIME , the fluid in the node transfers heat to (or receives heat from) its surroundings. Therefore, an element of fluid located at position $x = L - \ell$ at the beginning of a time step will experience a temperature change during the interval due to the net heat loss or gain it experiences while traversing the distance ℓ . Denoting the temperature of the fluid at $t = 0$, $x = L - \ell$, as TODP , the temperature of the fluid at $t = \text{DTIME}$, $x = L$, as TOP , and the temperature change of the fluid as it passes from $x = L - \ell$ to $x = L$ as DTC , the basic equation for determining the new

nodal fluid outlet temperature at $t = \text{TDIME}$ is

$$\text{TOP} = \text{TODP} - \text{DTC} . \quad (\text{A.58})$$

At any given instant, the only parameters specified for each node are the fluid mass flowrate, the inlet and outlet temperatures, and the external conditions affecting the heat transfer rate from the node (e.g., the ambient earth temperature for a pipe node or the fluid mass flowrate and inlet and outlet temperatures on the opposite side of a heat exchanger). The detailed nodal temperature profiles are not calculated, necessitating an approximation to be made in the determination of the fluid temperature TODP. An exponential temperature difference profile is assumed for each node, having the general form:

$$T_d(x) = \text{TN} \exp(-\alpha x) , \quad (\text{A.59})$$

where $T_d(x)$ = temperature difference between the fluid in the node and its surroundings at position x ,
 TN = temperature difference between the fluid in the node and its surroundings at the node inlet, and
 α = temperature difference decay constant.

Since the nodal outlet temperature difference, TD , is also

known, Eq. (A.59) can be solved to yield a value for α in terms of the instantaneous values of T_N and T_D :

$$-\alpha L = \ln \left(\frac{T_D}{T_N} \right), \quad (\text{A.60})$$

and the temperature difference profile becomes*

$$T_d(x) = T_N \exp \left[\ln \left(\frac{T_D}{T_N} \right) \frac{x}{L} \right]. \quad (\text{A.61})$$

It is also assumed that the slope of the fluid temperature profile at any point along the length of a node is directly proportional to the heat transfer rate from the node at that point and, hence, to the difference between the nodal fluid

*It should be noted that this exponential difference profile will yield the well-known log-mean temperature difference for steady-state heat conduction in a counterflow heat exchanger:

$$\begin{aligned} \pi dU \int_0^L T_d(x) dx &= \pi dUL \left[\frac{T_N}{\ln \left(\frac{T_D}{T_N} \right)} \right] \left[\frac{T_D}{T_N} - 1 \right] \\ &= AU \left[\frac{T_D - T_N}{\ln \left(\frac{T_D}{T_N} \right)} \right] \\ &= AU \Delta T_{\text{LMC}}. \end{aligned}$$

This profile is thus valid for steady-state heat transfer calculations and can be extended to transient calculations of the type made in the current model with little error in the resulting heat flows.

and external surroundings temperatures at that point. If the average slope of the fluid temperature profile for the entire node

$$T_S(av) = \frac{T_I - T_O}{L} \quad (A.62)$$

is the result of heat conduction from the node at the average log-mean temperature difference between the fluid and its surroundings

$$DTLM = \frac{T_D - T_N}{\ln \left(\frac{T_D}{T_N} \right)} \quad (A.63)$$

then the ratio of the average slope of the temperature profile in the region between $x = L - \ell$ and $x = L$ to the average slope for the entire node is given by the ratio of the log-mean temperature difference over that region to the average nodal difference. (i.e., The ratio of the profile slopes is equal to the ratio of the heat conduction rates.) Since the log-mean temperature difference over the region of the node from $x = L - \ell$ to $x = L$ is given by:

$$DTLMX = \frac{T_D - T_{DX}}{\ln \left(\frac{T_D}{T_{DX}} \right)} \quad (A.64)$$

with T_{DX} being calculated through Eq. (A.61) at $x = L - \ell$, the average slope of the nodal fluid temperature profile over this region of the node can be approximated by

$$T_S(x) = T_S(av) \left[\frac{DTLMX}{DTLM} \right] \quad (A.65)$$

Knowing the average slope of the temperature profile and the nodal fluid outlet temperature, it is possible to estimate the temperature of the fluid at $x = L - \ell$ to be:

$$TODP = TO + DL*(TI - TO)*\left(\frac{DTLMX}{DTLM}\right) \quad (A.66)$$

In order to calculate the temperature change of the fluid due to heat conduction effects as it flows from $x = L - \ell$ to $x = L$, it is necessary to determine the average heat transfer rate from the fluid to its surroundings over this region. Integrating the assumed exponential temperature difference profile from $x = L - \ell$ to $x = L$ yields the result that the average conduction heat transfer rate from the fluid is

$$\dot{Q}_c = AUF \left[\frac{TD - TDX}{\ln \left(\frac{TD}{TN} \right)} \right] \quad (A.67)$$

where AUF is the overall heat transfer coefficient for the total node. If it is assumed that the heat lost from the incremental volume of fluid in node length ℓ during DTIME results in a change in the average fluid temperature of magnitude DTC, energy conservation requires

$$\dot{Q}_c * DTIME = NTB * RHO * AC * \ell * CAP * DTC \quad (A.68)$$

Using Eq. (A.56) to express \dot{Q}_c in terms of the fluid mass flowrate and simplifying the resulting expression yields the average temperature change of the fluid due to conduction heat losses:

$$DTC = \frac{\dot{Q}_c}{MASS * CAP} \quad (A.69)$$

The expressions for the nodal fluid outlet temperature assuming no heat loss (Eq. (A.66)) and for the temperature change due to heat conduction effects (Eq. (A.69)) are combined through Eq. (A.58) to yield a new value for the nodal fluid outlet temperature at the end of the time step being studied. As indicated by the preceding discussion, the calculations leading to this temperature essentially consist of a comparison between the convective and conductive heat flowrates from the fluid in the final volume increment of the node. If the nodal thermal energy demand increases over its steady-state value, DTC will increase in magnitude and the outlet temperature will decrease as heat is removed from the fluid at a rate faster than it is supplied to the node by the steady-state fluid flowrate. If the demand decreases, the outlet temperature will increase as the fluid is swept through the node faster than heat is removed from it through conduction.

The basic nodal analysis outlined above for heat exchan-

ger nodes is also employed in the adjustment of pipe node outlet temperatures, with the only modifications being that the temperature "profile" of the "opposite node" is the constant earth temperature TAMB and that - due to the generally small differences between the pipe node inlet and outlet temperatures - all exponential temperature relations are approximated by linear functions.

Following computation of all the revised nodal outlet temperatures, the nodal inlet temperatures are set by requiring continuity of the fluid temperature profiles across the boundaries between adjacent nodes. For series nodes, the inlet temperature of a node is simply set equal to the new outlet temperature of the preceding node in the loop. The inlet temperatures to the pipe nodes following the primary loop secondary supply heat exchangers are given by the heat exchanger and bypass fluid mass-flowrate-average of the preceding node's inlet and outlet temperatures. The inlet temperature to the return pipe in a secondary distribution loop is the mass-flowrate-averaged outlet temperature from the parallel load center heat exchanger branches. The inlet temperatures to the consumer-side nodes of the load center heat exchangers are calculated in Program MAIN from the heat exchanger fluid flowrates, the fluid outlet temperature computed through the dynamic heat exchanger analysis in this subroutine, and the thermal demands obtained from linear

interpolation of the hourly loads computed in Subroutine DLOAD.

During the computation of the new nodal temperatures, Subroutine ENRG institutes a fairly complicated system of temperature monitoring and adjustment calculations to insure that the approximations made do not violate physical heat transfer laws or lead to mathematical relations exceeding the computational capabilities of the computer. The heat exchanger inlet and outlet temperature differences, TN and TD , are allowed to have minimum magnitudes of 10^{-6} °F to insure the finiteness of calculations involving logarithms of their ratio. Similarly, if the ratio TN/TD is within 10^{-6} of 1.0 (i.e., if the fluid temperature profiles are virtually parallel along the entire length of the heat exchanger), the energy flow calculations described above are performed using linear approximations to all the exponential relations, thereby avoiding the calculation of logarithms of 0, dividing by 0, etc. Although TN and TD are allowed to have opposite signs (indicating a crossing of the temperature profiles due to instantaneous transient conditions at either end of the heat exchanger), if this condition is detected, linear approximations to the exponential relations are employed to return the parameters to the unidirectional energy flow conditions satisfying the Second Law of Thermodynamics. Finally, if the computed nodal outlet temperatures are

found to violate the Second Law of Thermodynamics (e.g., if the outlet fluid temperature on the supply side of a heat exchanger is lower than the inlet fluid temperature on the demand side), finitely small temperature differences of magnitude 10^{-6} °F and of the correct sign are assigned between the errant values, and the system is allowed to correct itself through the continuing transient temperature adjustments made during the succeeding time intervals.

A.3.10 Precooler Monitor (Subroutine PREC)

The precise identification assigned to the TUS supply heat exchanger will depend upon the method and location in which heat is extracted from the power plant's coolant flowstream. However, for many plant types, this heat exchanger could take the form of a coolant precooler inserted into the turbine exhaust flowstream upstream of the fluid compressors [13]. Although this heat exchanger is not modelled by TDIST in the detail afforded to the TUS distribution loop units, its temperature and fluid flowrate parameters are monitored during each simulation time step to insure that the power plant-TUS energy interchange is at least obeying the physical constraints of the Second Law of Thermodynamics. The heat transfer coefficient of this heat exchanger is assumed to be "very large", such that any variations in the fluid temperatures on one side are immediately reflected in a temperature variation on the opposite side. In the current version of

TDIST, Subroutine PREC simply adjusts the power plant coolant flowstream inlet and outlet temperatures and the coolant flowrate to insure that the coolant temperatures are always greater than (or in the limiting case, equal to) the water temperatures on the TUS side of the heat exchanger and that the rate of heat transfer matches the power plant's net rate of thermal energy production.

A.3.11 Output (Subroutine PRV)

Subroutine PRV provides the primary output function for the code and is called at regular intervals specified by the user-defined print frequency code. Output data includes the nodal fluid mass flowrates and inlet and outlet temperatures, the instantaneous heat flowrates through each heat exchanger, information on the volume of water stored in both sections of the reservoir, the temperatures and flowrates on both sides of the TUS supply heat exchanger, and the instantaneous loop circulation pump pressure settings.

A.4 Simulation Run Options

Figure A.9 is a simplified flowchart for TDIST illustrating the major program components and decision control branches. Depending upon the type and extent of the system analysis desired, the code provides the flexibility of three general run options: (1) the calculation and distribution of the individual building thermal and electrical energy demands,

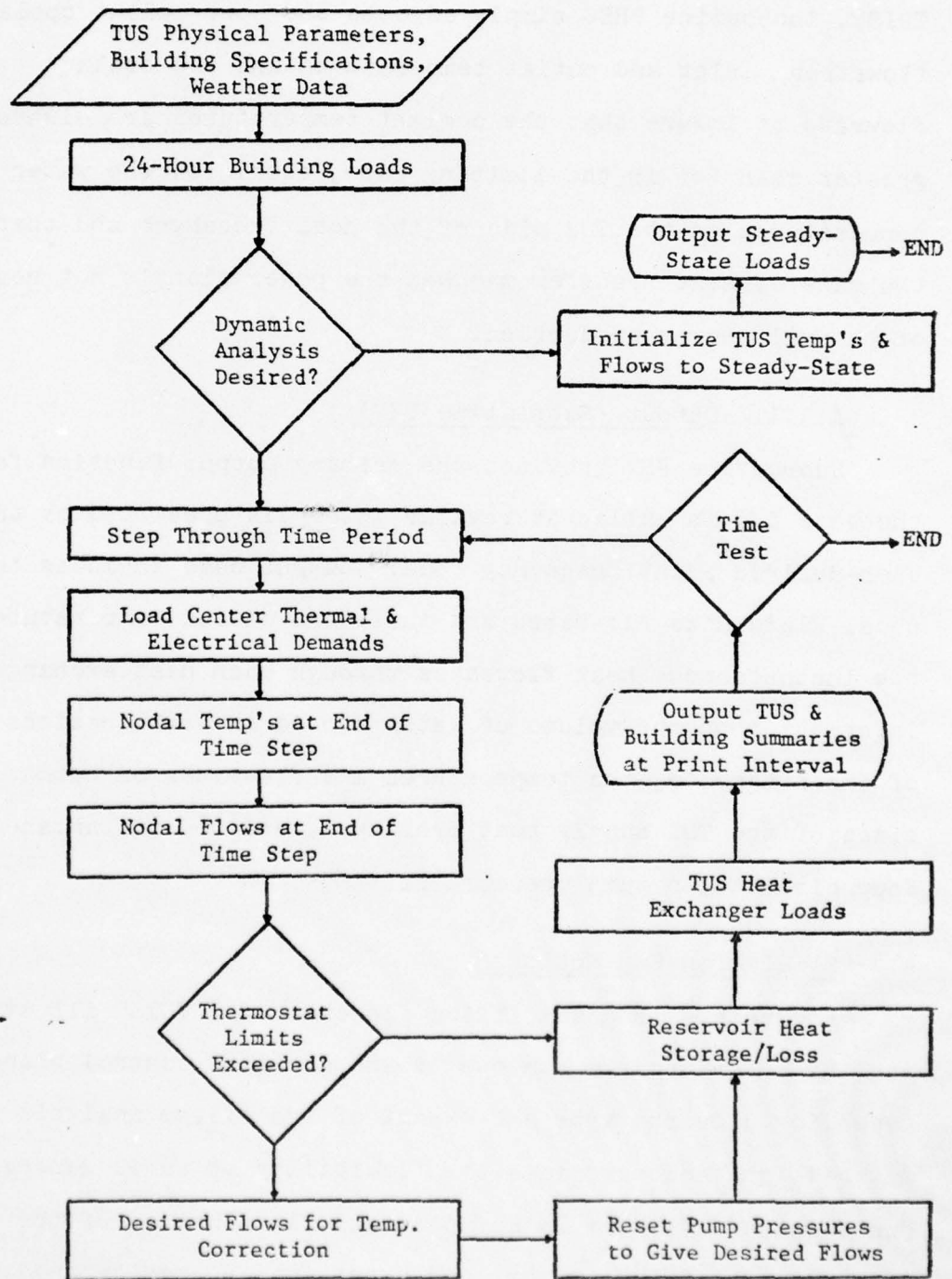


Figure A.9
Simplified TDIST Flowchart

(2) the iterative steady-state convergence of the TUS nodal temperatures and fluid flowrates, and (3) the full time-dependent TUS energy flow analysis. The following sub-sections describe briefly the computation format and parameter specifications for each of these options. Detailed input data requirements and output listings for the code are described in sections A.5 and A.6.

Two user-defined program flow control codes determine the simulation option(s) chosen for a given computer run and set the paths for the inter-subroutine data transfer and information outputs. The primary run control code is KODE, which determines the type of analysis to be performed. KODE = 0 allows either the calculation and output of the hourly building energy demands and the distribution of the initial loads according to the TUS load center heat exchanger locations or, depending upon the value of the second control code (IDES), it causes the TUS steady-state analysis to be performed. KODE = 1 indicates that the hourly building use and weather data specifications should be read in and, unless it is over-ridden by IDES, causes the dynamic system simulation to be performed. KODE = 2 indicates that the run is to be terminated. Whenever the value KODE = 0 is input to the program, the design run option code IDES must be specified. IDES = 0 indicates that the run to be made is simply the TUS steady-state analysis, based upon a computed single time instant building load distribution. IDES = 1

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TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND TOTAL--ETC(II)
AUG 76 J W STETKAR, M W GOLAY

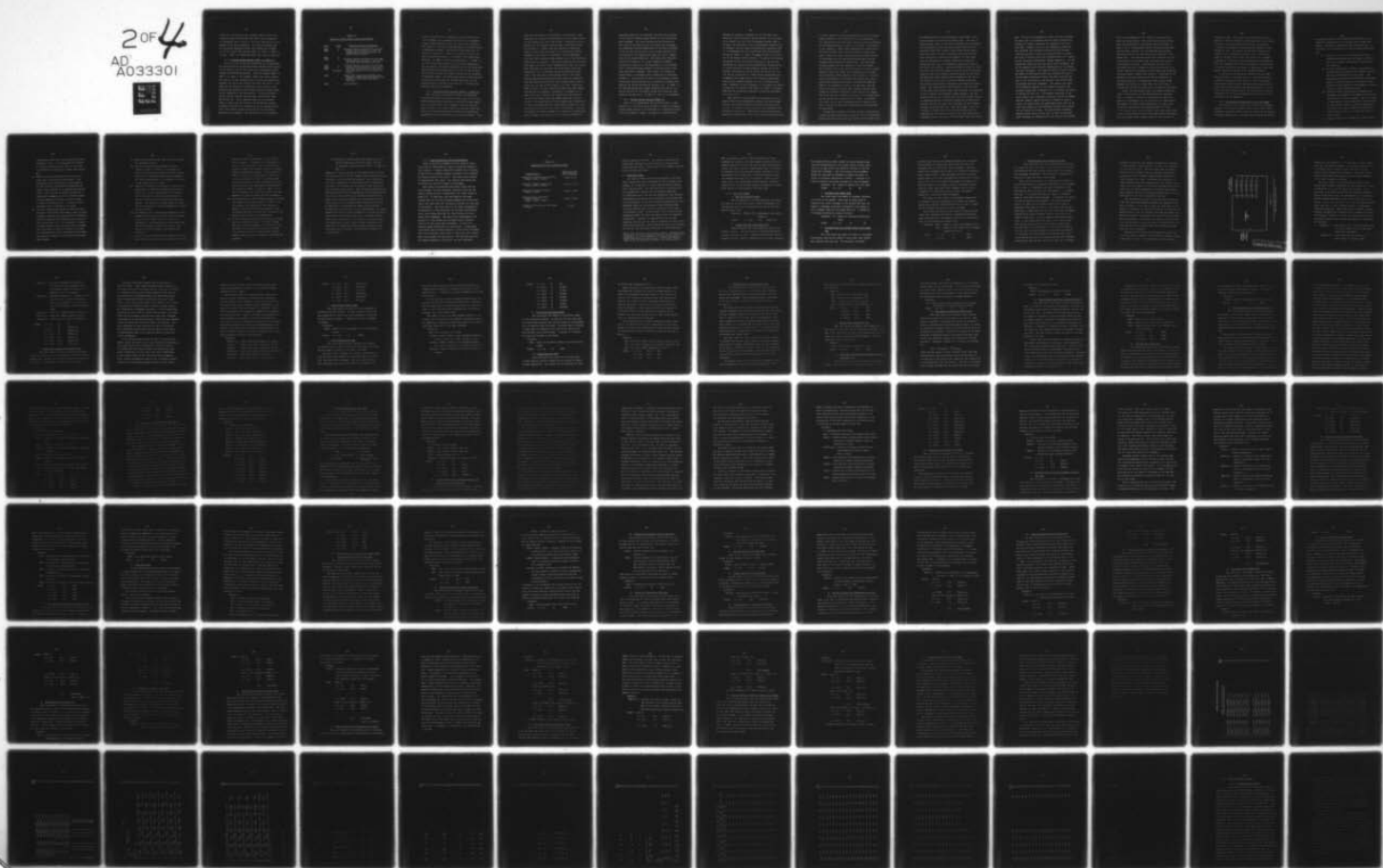
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allows the calculation of the building loads and their distribution among the specified load center heat exchangers, but terminates the run prior to the actual application of the demands to the heat exchangers. The hourly building loads for the entire simulation period are computed and printed out if the control code sequence $KODE = 0$, $IDES = 1$, $KODE = 1$ is input. Table A.9 summarizes these basic control functions.

A.4.1 Building Energy Demands ($KODE = 0$, $IDES = 1$)

This run option allows the calculation of the magnitudes and distribution of the building energy demands without applying the loads to the TUS load center heat exchangers or performing any TUS-related analyses. When the sequence $KODE = 0$, $IDES = 1$ is input to the program, single time instant values are read in for each building type's desired room temperature, equipment use factor and domestic hot water use factor. Also input are the ambient air temperature, wind velocity, wind direction and non-space-conditioning electrical demand factor for the community at the time instant. Subroutine QLOAD is called, and the computed building space conditioning loads are printed out. These loads are supplied to Subroutine DLOAD, in which they are scaled by the appropriate end-use equipment coefficients of performance and are aggregated into load center thermal energy demands and a total electrical demand for the community. The distribution of the building

TABLE A.9

TDIST RUN OPTION CONTROL CODE SPECIFICATIONS

<u>Code</u>	<u>Value</u>	<u>Resulting Program Performance</u>
KODE	0	Building demands calculated at one time instant and distributed to TUS: TUS steady-state analysis performed and system summary printed
IDES	0	
KODE	0	Building demands calculated at one time instant and distributed to TUS: building loads and distribution printed
IDES	1	
KODE	0	Building demands calculated at one time instant and distributed to TUS: building loads and distribution printed; hourly buildings loads calculated and printed
IDES	1	
KODE (sequence)	1	
KODE	1	Dynamic TUS simulation performed; TUS parameter summary and load distribution printed at user-specified output intervals
KODE	2	Run terminated

loads is printed out by building type at each load center heat exchanger, and a summary is provided of the aggregate thermal energy demands at each load center heat exchanger. When control is returned to Program MAIN, a succeeding value of KODE must be input. This value of KODE should not, in general, be equal to 0, unless it is desired to repeat the same calculation sequence or to perform a TUS steady-state analysis. If KODE = 2, the run is terminated. If KODE = 1, up to 24 hourly data values for the building temperatures and use factors, the hourly weather data, and the hourly non-space-conditioning demand factors are read in, are printed out in a set of input data summary tables, and are supplied to Subroutine QLOAD. An hour-by-hour space conditioning load calculation is performed for each building type, and the resulting hourly load data is printed out. Following this printout, the run is terminated.

A.4.2 TUS Steady-State Analysis (KODE = 0, IDES = 0)

This run option initializes the TUS to steady-state energy and momentum flow conditions based upon a set of computed building energy demands and a specified energy supply rate at the TUS supply heat exchanger. When the sequence KODE = 0, IDES = 0 is input, single time instant values are read in for each building type's desired room temperature, equipment use factor and domestic hot water use factor. Also

input are the ambient air temperature, wind velocity, wind direction and non-space-conditioning electrical demand factor for the community at that time instant. Subroutine QLOAD is called, and the computed building space conditioning loads are printed out. These loads are supplied to Subroutine DLOAD, in which they are scaled by the appropriate end-use equipment coefficients of performance and are aggregated into load center thermal energy demands and a total electrical demand for the community. From these loads and the user-specified supply and return water temperatures at each load center heat exchanger are calculated the steady-state fluid mass flowrates in all the consumer energy distribution piping nodes. The total space conditioning, domestic hot water, and non-space-conditioning electrical loads are subtracted from the specified power plant total thermal power output to obtain the net rate of heat supply to the TUS. Subroutine STDY is called, in which iterative steady-state heat balance calculations are employed to determine a converged set of nodal fluid mass flowrates and temperatures which satisfy the combined energy supply and demand conditions faced by the TUS. The resulting loop fluid flowrates are transmitted to Subroutine PRESS, and the corresponding steady-state loop circulation pump pressure settings are determined. Although the primary loop heat exchangers are analyzed in steady-state with no bypass flows around them, the parallel branch flow

regulation valves in the secondary loops are set according to the relative thermal energy demands at each load center heat exchanger. The fluid temperatures and flowrates on both sides of the power plant's TUS supply heat exchanger are determined, and the temperatures of the water contained in the hot and cold sections of the storage reservoir are initialized to the steady-state supply and return temperatures in the primary HTW loop. The steady-state TUS parameters are printed out in a nodal energy flow summary, followed by a printout of the distribution of the building space conditioning energy demands by building type at each load center heat exchanger. When control is returned to Program MAIN, a succeeding value of KODE must be specified. If KODE = 0, the user has the option of performing a second steady-state system analysis or of calling the building load analysis run option described in Section A.4.1. If KODE = 1, the computed steady-state nodal parameters are used to initialize the TUS for the dynamic energy flow simulation described in Section A.4.3. If KODE = 2, the run is terminated.

A.4.3 Dynamic System Analysis (KODE = 1)

Unless it is suppressed by the condition IDES = 1 (see section A.4.1), an input value of KODE = 1 causes the dynamic energy system analysis to be performed for a simulation period of up to 24 hours in length. Although it is theoretically

possible to specify a consistent set of TUS input data which will allow the dynamic system analysis to be successfully started the first time the program requires KODE to be input, the stability of the time-dependent simulation is so dependent upon the system initialization parameters that it is recommended that the steady-state TUS initialization run option (KODE = 0, IDES = 0) always be used as the front end of the dynamic system analysis. In addition to reducing the amount of hand calculations required of the user and minimizing the chances for TUS instabilities developing due to poorly specified initial parameter values, use of the internal initialization option allows the user to run low cost design calculations to insure system convergence prior to gambling the larger sums of time and money associated with the full dynamic analysis on a set of untested input data. Therefore, in the following, it is assumed that KODE = 1 is read into the computer upon return of control to Program MAIN from the steady-state analysis calculations described in Section A.4.2.

Input data for each building type consists of up to 24 hourly desired room temperatures, domestic hot water usage factors, and occupancy-related building use factors which are used to schedule internal equipment heat generation and forced air ventilation. Weather data inputs include hourly ambient air temperatures, wind velocities and wind directions.

An hourly community non-space-conditioning electrical energy demand schedule is also required for the determination of the components of the power plant load not directly associated with providing heating, cooling, or hot water to each person in the community. These hourly schedules are printed out in input data summary tables and are supplied to Subroutine QLOAD. Hourly net space heating and cooling energy demands are determined for each specified building type, and the building load schedules are printed out. The individual building demands are also supplied to Subroutine DLOAD, which computes and stores the resulting set of hourly thermal demands at each load center heat exchanger and the hourly total electrical energy demand for the community. Initialization calculations in Subroutine SET transfer the steady-state nodal parameters calculated in Subroutines STDY and PRESS to the appropriate nodes in the TUS model, and the primary loop and load center heat exchanger consumer-side thermostat reference temperature limits are set in Program MAIN based upon the converged steady-state fluid temperatures and the design values specified by the user. An internal time clock is set, and the dynamic analysis begins at the hour of the day at which the steady-state system parameters are specified.

During each simulation time step, linear interpolations between the stored hourly data values for the air temperature, system electrical loads, and load center heat exchanger ther-

mal demands provide the instantaneous energy demand conditions applied to the TUS and the power plant. The rate of thermal energy supply to the TUS is determined by subtracting the instantaneous total electrical energy demand from the specified power plant constant total thermal power output. Subroutine ENRG is called to determine the instantaneous fluid temperature distribution throughout the TUS, based upon the assumption of constant energy flow conditions during the time step, with temperature adjustments made at the end of the interval. Subroutine PRESS is called to determine the fluid friction pressure losses in each of the piping loops for the fluid flowrates existing during the time step, and Subroutine FLOWS adjusts these flowrates at the end of the interval, based upon a comparison between the actual circulation pump pressure settings and the computed pressure losses. The instantaneous fluid flowrate in the TUS side of the power plant thermal supply heat exchanger is calculated so as to transfer the available thermal energy to the TUS storage reservoir, and the hot and cold water storage volumes are adjusted through a comparison between the inter-section flowrate through the supply heat exchanger and the flowrate through the primary HTW loop. When the program control is returned to Program MAIN, the new fluid temperatures are compared with the reference values at the load center heat exchangers and at the outlets of the primary loop heat exchan-

gers. If none of the temperature limits has been exceeded, the time clock is incremented and the linear interpolation procedure is begun to determine the demands for the next time step. However, if any of the temperature limits has been exceeded, the thermostat-controlled fluid flowrate correction process is begun by calculating for the entire TUS a set of desired fluid mass flowrates which will exactly satisfy the given instantaneous thermal demands at: (1) the temperature limits for the load center heat exchangers, and (2) the desired fluid reference temperatures at the primary loop heat exchangers. The computed parallel branch flowrates are added to form desired total loop flowrates for each of the secondary distribution loops, and these flowrates are used in the calculation of the required flow splits among the primary loop heat exchangers. The primary loop nodal fluid flowrates computed in this manner for each of the secondary supply heat exchangers will, in general, be uniquely defined for each unit. To preserve continuity of the total primary loop flowstream, therefore, the heat exchanger with the largest computed flowrate is assumed to have no bypass, and bypass flows are established around each of the other units based upon the difference between this maximum and the desired unit flows. The desired heat exchanger/bypass flowrate ratio is then used to scale the existing nodal flowrates to effectively set the required flow splits

(but not the magnitudes of the flows) at the end of the time step being studied. The computed desired fluid flowrates are transmitted to Subroutines PRESS and FLOWS, in which a set of corresponding desired circulation pump pressure settings, scaled by the user-defined pump response sensitivity factor, are calculated and are applied to the system pumps. The existing system fluid flowrates are then re-calculated for the given time step based upon these revised pressure settings. (Waiting until the end of the following time step to update the flows could result in an overall inability to adequately follow large load variations occurring during a single time interval.) Following the re-setting of the pump pressures and the re-calculation of the fluid flowrates, the thermostat model returns normal program flow control to Program MAIN, the time clock is incremented, and the next time step's calculations are begun.

Output from the program during the dynamic system analysis is controlled by a user-defined printout frequency code. At regular intervals (as frequently as every time step or as infrequently as once each hour) an instantaneous TUS summary is printed which includes all the nodal fluid flowrates, temperatures, and energy demands, the total system thermal and electrical energy supply and demand conditions, the instantaneous circulation pump pressure settings, and the thermal energy storage reservoir fluid volume and

temperature data. Power plant sizing information is also printed to indicate whether the specified power plant thermal rating and electrical generation efficiency are adequate to supply the community's total electrical demands at that instant in time. Also output at each print interval is a summary of the instantaneous building space conditioning loads by building type at each load center heat exchanger. A summary of the thermal energy supply/demand mismatches at each heat exchanger in the TUS is provided to allow the user to monitor how closely the system is operating to ideal heat balance conditions throughout the simulation period.

At the end of the specified simulation period, $KODE = 2$ should be input to terminate the run. (Although provision is made for reading in other values of $KODE$ at this time, the analysis re-setting and continuation functions have not as yet been fully developed, and specification of 0 or 1 for $KODE$ would most probably lead to the calculation of invalid information due to residual parameters being held over from the dynamic system analysis.)

A.4.4 Coordination of Options to Aid in TES Design

When TDIST is used to aid in the design and performance analysis of a proposed community Total Energy System (TES), excessive computation effort, time and expense may be avoided by using a combination of the three basic program run options

to yield successively more detailed specifications of the community's demands and of the energy system design parameters. Some general guidelines which have been found to be helpful in the development of such an energy system model are:

- (1) Identify a set of up to 20 different building classifications which span the range of architectural and occupancy characteristics observed in the community.
- (2) For each classification, define a representative building unit which exhibits the typical structural and usage characteristics of its class. This building may be either an existing unit whose parameters are deemed typical, or it may be a representative model composed of the aggregate characteristics of several individual units.
- (3) Distribute these representative building units throughout the community according to the observed distribution of actual buildings. The total number of representative units specified at each location in the community should be chosen to approximate the total floor area (or some other equivalent energy demand index) of the actual buildings at that location.
- (4). Aggregate groups of buildings into energy demand

load centers, based upon their number density and similarity of use. In sizing these load centers, it should be remembered that each one connected to the TUS will be served by a single heat exchanger.

- (5) Design a proposed TUS piping layout which will supply HTW to the desired load centers. (Not necessarily every load center will be served by the TUS, since the economically optimum TES may require some buildings to be supplied all-electrically.) Each load center should be served by a single heat exchanger, up to five of which should be piped together in parallel to form a single secondary distribution loop. A maximum of five secondary loops is allowed in the system.
- (6) Once this rough system design has been specified, estimates of pipe sizes and lengths, pumps and heat exchanger locations, and pipe insulation parameters should be coded into the TDIST TUS input data formats (see Section A.5). The distribution (number of units served by each load center heat exchanger and total number of units not served by the TUS) and specifications of each representative building type should be coded into the TDIST building input data formats.

- (7) Specify the hourly weather data to be used during the simulation period.
- (8) Use the building design analysis run option (KODE = 0, IDES = 1, KODE = 1) to provide the space conditioning load profile for each building type over the simulation period and to aggregate the total energy demands to be supplied by the TUS at the beginning of the period.
- (9) Examine the computed load profiles to identify any questionable or invalid building data specifications (i.e., if the load profile is not "reasonable", identify the controlling load component and the building parameters determining that component). Any parameter revisions should be verified by re-running the code and generating a corrected set of loads.
- (10) If necessary, due to significant imbalances in the thermal load distribution within a given secondary loop, the load centers should be redefined or rearranged to yield reasonably uniform loads among the heat exchangers in each loop, and the code should be re-run to generate the revised load distribution.
- (11) Once the building loads have been verified, use the given demand distribution and specifications of the

desired TUS fluid temperatures to size the TUS heat exchangers. In general, it is advisable to run the code twice during this sizing exercise, unless the peak hourly demands occur at the beginning of the simulation period. One run (KODE = 0, IDES = 1, KODE = 1, as summarized in steps 8-10) is used to generate the hourly building demands and the TUS loads to be used in specifying the required initial system temperatures and flowrates; the second run (KODE = 0, IDES = 1, KODE = 2) is used to determine the single time instant TUS peak demands to be used in sizing the heat exchangers.

- (12) After specifying the heat exchanger designs, perform the steady-state analysis (KODE = 0, IDES = 0) of the system at the beginning of the simulation period to insure that the system design is self-consistent and that the system will converge to the desired fluid flowrates and temperatures.
- (13) If necessary, make design revisions (such as changing heat exchanger ratings, the initial primary HTW loop fluid mass flowrate, or the sizes of the distribution loop piping) and re-run the steady-state analysis until the desired fluid flowrate, pressure loss, and fluid temperature conditions are achieved.

- (14) Perform the time-dependent TES simulation by calling the steady-state analysis option, followed by the dynamic system analysis (KODE = 0, IDES = 0), KODE = 1).

Expansion of the run options in this manner from the building load analysis to the full dynamic system simulation allows the user to clearly define the community loads (which are, of course, independent of the assumed method of energy supply) prior to performing any TES analyses other than choosing a proposed piping layout. Once the proper building models have been specified and the appropriate TUS configuration has been chosen, the resulting heat exchanger designs and proposed fluid flowrate and temperature specifications may be fully tested, and any required system design revisions may be made prior to performing the dynamic system analysis. Following full specification of the system design, the dynamic analysis run option provides information as to how the particular design chosen behaves over time. Although possibly seeming over-conservative in its approach to system design, this methodology allows a logical system development and, based upon the computation time estimates outlined in the following section, provides a cost-effective sequence of system analysis.

A.4.5 Computer Execution Time Specifications

TDIST is written in FORTRAN IV and is directly compatible with the IBM System 370 computer using the FORTRAN H-level compiler. Program compilation requires the allocation of 288 K bytes of working storage; execution of the compiled load module requires 128 K bytes. The source deck consists of approximately 1800 cards. The compiled load module may be stored on a total of 8 tracks of disk space.

When using a pre-compiled load module called from reserve storage, the user may expect execution times for the various program options to approximate the values listed in Table A.10. In each case, the time shown is the total elapsed time for the run, including program set-up and blocking of the output data for subsequent printing; all times are in CPU-minutes. The lower limit of the range corresponds to the analysis of a TUS containing two secondary distribution loops, one serving three and the other serving five load center heat exchangers. The upper limit corresponds to the analysis of a TUS having four secondary loops, serving a total of 18 load center heat exchangers. A total of 11 building types are specified for each system. Steady-state system input data includes estimates of the initial secondary loop fluid flowrates, which serve to reduce the total convergence time required for each system. The time step size for the dynamic analyses is 0.001 hour, and each simulation

TABLE A.10

REPRESENTATIVE OPTION EXECUTION TIMES

<u>Program Option</u>	<u>Execution Time (CPU - minutes)</u>
Single-time building load analysis (KODE=0, IDES=1, KODE=2)	0.096 - 0.112
24-hour building load analysis (KODE=0, IDES=1, KODE=1)	0.110 - 0.123
Steady-state system analysis (KODE=0, IDES=0)	0.105 - 0.108
24-hour dynamic simulation (DTIME = 0.001) (KODE=0, IDES=0, KODE=1)	4.374 - 8.691
Program compilation and load module storage	0.692

covers a period of 24 hours. The dynamic simulations are initialized internally by first calling the steady-state system analysis option. Data output for the dynamic analyses occurs at every half hour.

A.5 TDIST Input Data

All input to TDIST is from cards supplied by the user. Since fixed-format input statements are used throughout the program, it is important to follow the data format instructions outlined below. The data which must be specified for each program run* consists of four general categories:

- (1) specifications of the physical parameters, heat transfer coefficients, and average fluid conditions in each TUS node,
- (2) specifications of the heat transfer characteristics, time-dependent usage, and distribution of each building type,
- (3) hourly weather data, and (4) program run control and initialization codes. To some extent, these categories are segregated within the input data deck for ease of parameter modification. However, the segregation is by no means complete, and care must be taken to formulate the deck in the exact order presented. Input diagnostics exist, but are minimal and are only available during runs in which Subroutine

*Input data flexibility is extremely limited. Depending upon the type of run to be performed, some data values may be left unspecified, but their locations in the data deck must be filled with blanks or dummy values to facilitate correct input of all the required information (see Section A.5.3.)

STDY is executed; errors in data specification or card punching will appear in the input summary printed with each program execution, but will not usually cause termination of a given run until a serious computational error is detected. To minimize costly input-related errors, therefore, it is recommended that the data deck be checked carefully before each program execution, and, if possible, a short program option (e.g., the steady-state system analysis) should be executed prior to any extended dynamic simulations to internally verify the correctness of the input data.

A.5.1 Data Card Format

1. Run Identification Cards

For the purposes of run identification, the first two cards in the data deck should contain alphanumeric run descriptions which will be printed at the top of the first page of output data.

Variables: TITLE, CITY - alphanumeric run identifications

Format: c.c. 1-80 20A4 TITLE,CITY

2. Primary HTW Loop Node Number Card

This card inputs the total number of nodes in the primary HTW loop. For the purposes of system determination, a node is defined as either a length of pipe having constant diameter and heat transfer characteristics or a heat exchanger.

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The primary HTW loop nodes include the pipes supplying heat from and returning heat to the thermal energy storage reservoir, but do not include the reservoir sections or the TUS supply heat exchanger. Pipe runs between heat exchangers within the loop must be included, no matter how short, to result in effective calculation of losses. A maximum of 13 nodes is allowed, including a maximum of 5 heat exchangers.

Variables: NH - number of primary HTW loop nodes

Format: c.c. 1-3 I3 NH

3. Secondary Loop Number Card

This card inputs the number of secondary distribution loops in the system. Since each of these loops is supplied from a heat exchanger in the primary HTW loop, the number of secondary loops must correspond to the number of heat exchanger nodes in the primary HTW loop. A maximum of 5 secondary distribution loops is allowed.

Variables: LS - number of secondary distribution
 loops

Format: c.c. 1-3 I3 LS

4. Secondary Loop and Consumer Branch Node Number Card

This card inputs the number of nodes in a secondary distribution loop and the number of load center heat exchangers supplied from the loop. The secondary loop nodes

specified must include the primary/secondary heat exchanger, the secondary loop supply and return pipes for this heat exchanger, and the load center heat exchangers. The load center heat exchangers are assumed to be supplied in parallel from a common header. Nodes including the pipes from this supply header to the heat exchangers and from the heat exchangers to the loop return header should not be included; each parallel branch in a secondary loop will therefore contain only the single load center heat exchanger node it serves. A maximum of 13 nodes per loop is allowed, including a maximum of 5 load center heat exchangers.

The number of load center heat exchangers supplied by a secondary loop must correspond to the number of parallel branch heat exchanger nodes specified for the loop. A maximum of 5 parallel branches per loop is allowed.

Since this card specifies the number of nodes and load center heat exchangers for only one secondary distribution loop, one card must be supplied for each of the loops specified on the Secondary Loop Number card.

Variables: ND(L) - number of nodes in secondary loop L
 NB(L) - number of load center heat exchangers
 supplied by loop L

Format:	c.c. 1-3	I3	ND(L)
	c.c. 4-6	I3	NB(L)

5. Node Dimension and Location Code Card

This card inputs the node identification and location codes for any of the nodes in the system and the physical dimensions and heat transfer coefficient for the pipe or heat exchanger represented. One card must be supplied for each of the nodes specified in the system.

Basic node identification is accomplished through the use of three indicators, generally designated in the program as K, L, and N. K identifies the major subsection of the distribution system in which the node appears: 1 = primary HTW loop, 2 = secondary distribution loops, 3 = consumer sides of load center heat exchangers. L indicates the specific loop in which the node appears: for the primary HTW loop $L = 1$; each of the secondary distribution loops is numbered in the order in which it is supplied from the primary loop, L ranges from 1-5; the load center heat exchangers supplied from a given secondary loop are coded with the L number of that loop. N is the specific node number within a loop: in the primary HTW loop, node 1 is the outlet pipe from the hot water section of the storage reservoir and the last node is the return pipe to the cold water section from the final secondary supply heat exchanger (maximum of $N = 13$ nodes); in each secondary distribution loop, node 1 is the outlet pipe from the primary/secondary heat exchanger supplying the loop and the last node is that heat exchanger;

parallel branch nodes are numbered consecutively according to their schematic representation (see Fig. A.10) (maximum of $N = 13$ nodes per loop). The load center heat exchangers served by each secondary loop are numbered consecutively according to their schematic representation (maximum of 5 heat exchangers per loop). Following this convention, a nodal parameter with the designation $X(2,3,8)$ would be associated with node number 8 in the third secondary distribution loop; $Y(3,2,4)$ would correspond to the fourth load center heat exchanger served by the second secondary loop; $Z(1,1,1)$ would apply to the first primary HTW loop node.

The identification codes on this card must include the N for the node being specified (K and L are supplied internally according to the order in which the nodal data is supplied), an indicator for whether the node is a series flow or parallel branch node (all primary loop nodes are series, the parallel secondary loop branches and load center heat exchangers are parallel), an indicator for whether or not the node is a heat exchanger, and an indicator for whether or not the node contains the circulation pump for the loop (one pump node per loop is allowed).

Dimensional data which must be supplied includes the nodal flow channel diameter (in feet) and the physical length of the node (in feet). For pipe nodes, the flow channel

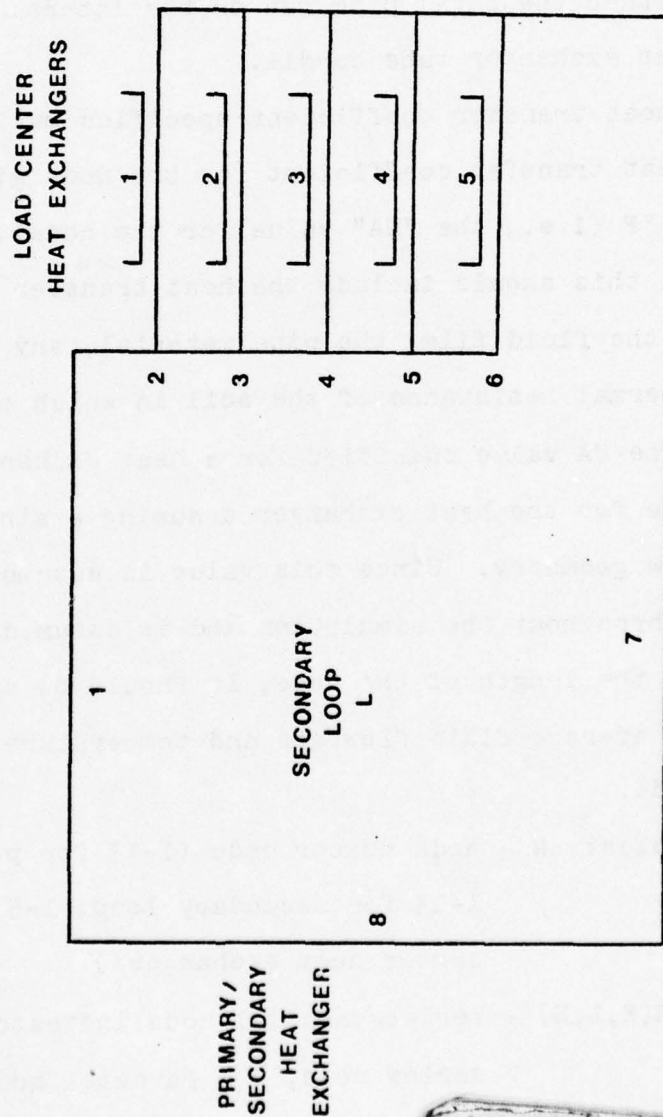


Figure A.10
Secondary Loop and Load Center Heat Exchanger
Node Numbering Conventions

diameter is the specified I.D. of the pipe; for heat exchangers, the flow channel diameter to be specified is the I.D. of a single tube or channel between the tubes (not the overall heat exchanger shell diameter). The length of the node is either the total pipe run or the lateral dimension of the heat exchanger tube bundle.

The heat transfer coefficient specified must be the overall heat transfer coefficient for the node given in units of BTU/hr-°F (i.e., the "UA" value for the node). For a pipe node, this should include the heat transfer characteristics of the fluid film, the pipe material, any insulation, and the thermal resistance of the soil in which the pipe is buried. The UA value specified for a heat exchanger must be the total value for the heat exchanger assuming a single-pass counterflow geometry. Since this value is assumed to remain constant throughout the simulation and is assumed to be uniform along the length of the node, it should be specified at the design average fluid flowrate and temperature conditions for the node.

Variables: N - node number code (1-13 for primary loop, 1-13 for secondary loop, 1-5 for load center heat exchangers)

ISER(K,L,N) - series/parallel node indicator (0 = series node, 1 = parallel node)

IEX(I,L,N) - pipe/heat exchanger node indicator

(0 = pipe node, heat exchanger nodes are numbered consecutively from 1 to a maximum of 31 for the system)

IPMP(K,L,N) - pump node indicator (0 = no pump in node, pump nodes are numbered consecutively from 1 to a maximum of 6, at one node each for the primary loop and secondary loops)

DIA(K,L,N) - nodal flow channel diameter (in feet)

LONG(K,L,N) - nodal flow channel length (in feet)

AUF(K,L,N) - nodal overall UA value (in BTU/hr°F)

Format:	c.c. 1-3	I3	N
	c.c. 4-6	I3	ISER(K,L,N)
	c.c. 7-9	I3	IEX(K,L,N)
	c.c. 10-12	I3	IPMP(K,L,N)
	c.c. 13-19	F7.4	DIA(K,L,N)
	c.c. 20-30	E11.4	LONG(K,L,N)
	c.c. 31-41	E11.4	AUF(K,L,N)

6. Nodal Fluid Parameter Information Card

This card inputs the initial fluid mass flowrate, nodal fluid inlet and outlet temperatures, and average fluid specific heat, density and viscosity for any of the nodes in the system. One card must be supplied for each node.

The nodal fluid mass flowrate must be specified in units of lbm/hr. Nodal values supplied should correspond to the design values for the system initial conditions and should be consistent with the flow channel geometry within each of the loops (e.g., the series primary loop nodes should each have the same mass flowrate to preserve continuity of the flow). In all cases, the primary loop flowrate must be given as accurately as possible, since it serves as basic input to the steady-state convergence subroutine. If the steady-state subroutine is to be used for system initialization, the flowrates for the secondary loop and load center heat exchanger nodes need not be specified precisely, since they are computed internally during the system convergence calculations. However, estimates of these flowrates are used to initialize the steady-state calculations, and the data provided should be approximately equal to the expected values to speed the system convergence.

If the steady-state analysis is used to initialize the dynamic system calculations, the only temperatures required as input data are the inlet temperature to the first node in the primary HTW loop (which becomes the constant TUS fluid supply temperature) and the supply and return temperatures on the consumer sides of the load center heat exchangers. These consumer temperatures should be set according to specifications for the end-use equipment served, and the actual

temperatures are allowed to vary from these design values during the simulation according to the internally-defined thermostat control limits.

The specified nodal fluid specific heat, density and viscosity should correspond to design values calculated from the average fluid temperature conditions for the node. The specific heat must be given in units of BTU/lbm-°F, the density in lbm/ft³, and the viscosity in lbm/ft-hr. These values are assumed to be constant throughout the simulation and uniform along the length of the node; discontinuities at nodal boundaries are allowed to account for variations in the average nodal fluid temperature around each of the loops. Since these parameters are used in the determination of the specific nodal heat and fluid momentum transfer rates, the values specified should be as precise as possible within the nodal averaging constraints outlined above.

Variables:

MASS(K,L,N) - nodal fluid mass flowrate (in lbm/hr)
TI(K,L,N) - nodal fluid inlet temperature (in °F)
TO(K,L,N) - nodal fluid outlet temperature (in °F)
CAP(K,L,N) - nodal fluid specific heat (in BTU/lbm-°F)
RHO(K,L,N) - nodal fluid density (in lbm/ft³)
MU(K,L,N) - nodal fluid viscosity (in lbm/ft-hr)

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Format:	c.c. 1-11	E11.4	MASS(K,L,N)
	c.c. 12-18	F7.2	TI(K,L,N)
	c.c. 19-25	F7.2	TO(K,L,N)
	c.c. 26-32	F7.4	CAP(K,L,N)
	c.c. 33-39	F7.4	RHO(K,L,N)
	c.c. 40-46	F7.4	MU(K,L,N)

7. Heat Exchanger Number Card

This card inputs the number of heat exchangers in the HTW distribution system. Included should be the secondary supply and the load center heat exchangers, but not the TUS supply heat exchanger. A maximum of 31 heat exchangers is allowed.

Variables:

NEXCH - number of heat exchangers in the distribution system

Format:	c.c. 1-3	I3	NEXCH
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8. Heat Exchanger Data Card

This card inputs the heat exchanger code number, the identification codes for its supply and demand side nodes, and the number of parallel flow tubes it contains.

The system heat exchangers are numbered consecutively from the first heat exchanger in the primary HTW loop to the last load center heat exchanger. The code number for the heat exchanger given on this card should correspond to the

values for IEX(K,L,N) given on the two Node Dimension and Location Cards containing its dimensions and heat transfer characteristics. A maximum of 31 heat exchangers are allowed in the system.

For the purposes of heat exchanger identification, the supply-side nodes for the primary/secondary heat exchangers are the primary HTW loop nodes serving them; the supply-side nodes for the load center heat exchangers are the parallel secondary loop nodes serving them.

The number of tubes in a heat exchanger should be consistent with the specified heat transfer coefficient, physical dimensions, single-pass counterflow geometry, and design fluid flow conditions for the heat exchanger.

Variables:

NEX - heat exchanger code number

K1(NEX), L1(NEX), N1(NEX) - heat exchanger supply-side identification codes [NEX = IEX(K1, L1, N1)]

K2(NEX), L2(NEX), N2(NEX) - heat exchanger demand-side node identification codes [NEX = IEX(K2, L2, N2)]

NTB(NEX) - number of parallel flow tubes in heat exchanger

Format:	c.c. 1-3	I3	NEX
	c.c. 9-11	I3	K1(NEX)
	c.c. 12-14	I3	L1(NEX)
	c.c. 15-17	I3	N1(NEX)
	c.c. 23-25	I3	K2(NEX)
	c.c. 26-28	I3	L2(NEX)
	c.c. 29-31	I3	N2(NEX)
	c.c. 37-41	I5	NTB(NEX)

9. Circulation Pump Number Card

This card inputs the number of circulation pumps in the distribution system. To simplify the loop pump pressure requirement analysis and fluid acceleration calculations, only one pump per loop is allowed. The pumps must be located in pipe nodes as indicated by the IPMP(K,L,N) code on the Node Dimension and Location Cards. A maximum of 6 circulation pumps are allowed in the system.

Variables:

NPMP - number of circulation pumps in the distribution system

Format:	c.c. 1-3	I3	NPMP
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10. Storage Reservoir Card

This card inputs the initial hot and cold water storage reservoir section volumes and the initial hot water storage temperature. The volumes must be specified in units

of ft^3 and the temperature in $^{\circ}\text{F}$.

Since variations in the hot water section volume during the simulation determine the required storage capacity for system load smoothing, the exact values of the initial volumes are not critical to the system heat flow calculations. However, the volumes should be specified large enough to preclude emptying of either section during the time period under investigation. The reservoir sections are assumed to be located between the TUS supply heat exchanger and the primary loop supply and return pipes; no node identification codes are required for the reservoir.

The initial hot water storage temperature should correspond to the specified fluid inlet temperature for the first primary loop node. This temperature is held constant throughout the simulation unless the hot water reservoir section is emptied.

Variables:

HVO - hot water storage section initial volume (in ft^3)

CVO - cold water storage section initial volume (in ft^3)

THW - hot water storage temperature (in $^{\circ}\text{F}$)

Format:	c.c. 1-11	E11.4	HVO
	c.c. 12-22	E11.4	CVO
	c.c. 23-29	F7.2	THW

11. TUS Supply Heat Exchanger Data Card

This card inputs the power plant coolant inlet and outlet temperatures, the initial fluid mass flowrate, and the fluid specific heat on the supply-side of the TUS supply heat exchanger. The temperatures must be specified in °F, the flowrate in lbm/hr, and the specific heat in BTU/lbm-°F.

The supply side inlet and outlet temperatures are held constant throughout the simulation unless the heat flow across the heat exchanger demands that either one or both be modified to comply with the Second Law of Thermodynamics. The inlet temperature should be specified high enough to provide heat transfer to the primary HTW loop inlet fluid; the outlet temperature should be as low as possible for efficient power plant operation, yet high enough to provide heat transfer to the primary loop return fluid.

The exact value for the coolant mass flowrate required to transfer the available heat within the specified temperature limits is computed internally during the initialization of the system. However, a non-zero value for this parameter should be supplied to the program to avoid the possibility of computational overflow errors during this portion of the simulation.

The specific heat of the fluid should correspond to the value calculated for the average fluid temperature in the

heat exchanger; the specific heat remains unchanged during the simulation.

Variables:

THG - coolant inlet temperature ($^{\circ}\text{F}$)

TCG - coolant outlet temperature ($^{\circ}\text{F}$)

MGAS - coolant mass flowrate (lbm/hr)

CAPG - coolant specific heat (BTU/lbm- $^{\circ}\text{F}$)

Format:	c.c.1-7	F7.2	THG
	c.c.8-14	F7.2	TCG
	c.c.15-25	E11.4	MGAS
	c.c.26-32	F7.4	CAPG

12. Ambient Earth Temperature Card

This card inputs the ambient earth temperature at the average burial depth for the distribution piping. It is used in the calculation of heat losses from buried pipes and conduction losses to the earth from buildings. The earth temperature must be given in $^{\circ}\text{F}$.

Variables:

TAMB - ambient earth temperature (in $^{\circ}\text{F}$)

Format: c.c. 1-7 F7.4 TAMB

13. Power Plant Thermal/Electric Energy Conversion Efficiency Card

This card inputs the overall power plant thermal/electric energy conversion efficiency as the ratio of the

electrical energy output from the generators to the thermal energy content of the fuel burned. It is used in determining the total energy consumption for electricity production in conjunction with the heat available to the thermal system. The efficiency should be given as a decimal fraction.

Variables:

EFF - power plant overall thermal/electric energy conversion efficiency (decimal fraction)

Format: c.c. 1-7 F7.4 EFF

14. Pump Response Sensitivity Factor Card

This card inputs the circulation pump response sensitivity factor for all the pumps in the system. This factor is applied to the difference between the projected pressure settings and the existing pump pressures to provide an accelerated response to the loop fluid flowrates when the thermostat is activated. A factor of F results in the pumps being set at pressures equal to the required pressure plus F times the difference between the required and existing pressures. Therefore, a factor of 2.0 results in settings of:

$$P_{\text{set}} = 3P_{\text{required}} - 2P_{\text{existing}}$$

Higher factors result in faster response times; very fast response times should be avoided since they can result in overshooting of the desired flow conditions and instabilities in subsequent heat flow calculations. The factor is dropped from the pump settings when the loop flows have accelerated

to within 1% of the desired values.

Variables:

PSENS - pump response sensitivity factor

Format: c.c.1-7 F7.4 PSENS

15. Time Increment and Print Interval Data Card

This card inputs the number of time increments per hour to be used in the transient calculations, the number of increments between system information printout, and the size of one time step. The number of increments per hour and the number of increments between printouts should be given as integer numbers; the number of increments per hour must be a whole number multiple of the number of increments per printout. A minimum of 1 printout per hour is allowed (i.e., the number of steps between printouts = the number of steps per hour). The time step size should be given as a decimal fraction of an hour.

A small time step size results in increased accuracy in the dynamic calculations by allowing a closer modelling of the continuously varying system conditions. However, short time steps also result in considerable increases in the total computational time for any given simulation. Conversely, longer time steps reduce both computation time and modeling accuracy. For each simulation, a compromise value must be chosen which reflects the more important of the computational parameters desired for the given run.

Although it is possible to print the entire set of system parameters for every time step in the simulation, it is advisable both for run time and data reduction purposes to print out this data only at a frequency high enough to give meaningful output. If the system excitation conditions vary greatly from hour to hour, a print interval of once every quarter hour may be necessary to yield the desired detail in the output; for slowly varying conditions, an output listing once every hour could be sufficient.

Variables:

NSTEP - number of time steps per hour

NPRNT - number of time steps between printouts

DTIME - single time step size (as a decimal fraction of an hour)

Format:	c.c. 1-5	I5	NSTEP
	c.c. 6-10	I5	NPRNT
	c.c. 11-18	F8.5	DTIME

16. Building Type Number Card

This card inputs the number of different building types to be served by the total energy system. For the purposes of determining this number, a distinct building type is defined as one having representative physical dimensions, occupancy, room temperature requirements, and materials heat transfer characteristics. Buildings used for similar purposes and having similar physical characteristics should be placed

in a single type class, even though there may be differences in their detailed construction or layout. A maximum of 20 different building types is allowed.

Variables:

NTYPE - number of building types served by system

Format: c.c. 1-3 I3 NTYPE

17. Bulding Material Heat Transfer Parameter Card

This card inputs the exposed areas and thermal resistances of the walls, windows, roof, and ground-contact material for the building type specified by its building code number. The areas must be given in ft^2 and the thermal resistances in $(\text{BTU/hr-ft}^2\text{-}^\circ\text{F})^{-1}$. One card must be input for each building type as specified on the Building Type Number Card.

The building type code number is simply an integer which identifies the particular building type being specified. Types should be numbered consecutively for any given simulation; a maximum of 20 building types is allowed.

The areas specified should be the total exposed surfaces for each component of the building. TDIST assumes all buildings to be square and symmetrical and it will use 25% of the total specified areas of the walls and windows when calculations are performed on a per-wall basis. The ground-contact area of the building should be the total basement surface area in contact with the surrounding soil or the surface area

of the building's base slab, if no basement exists. The roof area, if the roof is not flat, should be the horizontal projection of the total pitched-roof area. The parameter values should be typical for the similar buildings within the type class being specified. It is recommended that buildings within the community being studied first be classified according to type and then that a representative building be chosen as the norm for each grouping. Physical dimensions and construction materials specified for each building type should be consistent with actual data for these norms. Care should be taken to include in the specified areas only those sections of the building exposed to the external elements, since the heat transfer calculations assume losses from the building only to the surrounding air and the earth. The heat transfer characteristics for compound materials must be correctly combined to produce a single coefficient for the particular section of the building specified. Wall and roof thermal resistances should include the inner surface film convection resistance and the composite thermal resistance of the materials from which they are constructed; the code computes the outer surface convection resistance based upon a specified surface roughness coefficient and the instantaneous wind velocity, and adds this surface term to the user-supplied resistance to produce a total heat transfer coefficient for the component being analyzed. If walls are constructed differently throughout the building, the various

section values should be combined to produce a single average wall coefficient for the building. When specifying these parameters, it should be remembered that all factors influencing the net transfer of heat from the interior of the building to its surroundings must be included but that heat transfer within the building itself is neglected.

Variables:

I - building type code number

AW(I) - building exposed wall area (in ft^2)

RTW(I) - average wall thermal resistance (in $\text{hr-ft}^2\text{-}^\circ\text{F/BTU}$)

AWD(I) - building window area (in ft^2)

RTWD(I) - average window thermal resistance (in $\text{hr-ft}^2\text{-}^\circ\text{F/BTU}$)

AR(I) - building roof area (in ft^2)

RTR(I) - average roof thermal resistance (in $\text{hr-ft}^2\text{-}^\circ\text{F/BTU}$)

AF(I) - building exposed floor/basement area (in ft^2)

RTF(I) - ground-contact material thermal resistance
(in $\text{hr-ft}^2\text{-}^\circ\text{F/BTU}$)

Format:	c.c. 1-2	I2	I
	c.c. 3-10	F8.2	AW(I)
	c.c. 11-18	F8.3	RTW(I)
	c.c. 19-26	F8.2	AWD(I)
	c.c. 27-34	F8.3	RTWD(I)

c.c. 35-42	F8.2	AR(I)
c.c. 43-50	F8.3	RTR(I)
c.c. 51-58	F8.2	AF(I)
c.c. 59-66	F8.3	RTF(I)

18. Building Air Infiltration Factor Card

This card inputs the infiltration air flow coefficients C and N and the infiltration crack dimensions for the windows and doors of the building type specified by its code number. Also input are the coefficients C and N for the building's walls. One card must be supplied for each building type as specified on the Building Type Number Card.

The coefficients C and N (obtained from Table A.3) are used to translate the combined effects of wind and stack effect induced pressure differences into air flowrates in CFM per linear foot of crack (or, in the case of the walls, CFM per square foot of surface area). Since the infiltration air flowrate for the building is directly proportional to C, extreme care should be exercised in selecting values from the extremely wide range of available specifications which accurately reflect the representative building's construction characteristics. The value of C input for the windows should be the sum of the window and frame coefficients; N should be the average of the window and frame coefficients.

Because air generally flows into a building on one side

and out of the building on the opposite side, the crack lengths specified around doors and windows should be 50% of the total cracks measured for the building to avoid double volume counting in the flow calculations.

Variables:

I - building type code number

DCL(I) - door crack length (in ft.)

DINC(I) - door crack flow coefficient C

DINN(I) - door crack flow coefficient N

WDCL(I) - window crack length (in ft.)

WDINC(I) - window crack flow coefficient C

WDINN(I) - window crack flow coefficient N

WINC(I) - wall crack flow coefficient C

WINN(I) - wall crack flow coefficient N

Format:	c.c. 1-2	I2	I
	c.c. 3-10	F8.3	DCL(I)
	c.c. 11-18	F8.3	DINC(I)
	c.c. 19-26	F8.3	DINN(I)
	c.c. 27-34	F8.3	WDCL(I)
	c.c. 35-42	F8.3	WDINC(I)
	c.c. 43-50	F8.3	WDINN(I)
	c.c. 51-58	F8.3	WINC(I)
	c.c. 59-66	F8.3	WINN(I)

19. Building Miscellaneous Data Card

This card inputs codes for the surface materials of the walls and roof, the height, and the nominal maximum ventilation air flowrate for the building specified by its type code number. The building height must be specified in ft. and the air flowrate in CFM. One card must be input for each building type as specified on the Building Type Number Card.

The wall and roof surface material type codes are used as indices for internally-stored surface roughness coefficients used in the calculation of the surface convection thermal resistances. The codes should be input as integer values according to the following classifications:

- | | |
|--------------------------|-----------------------------------|
| 1 - stucco | 4 - clear pine |
| 2 - brick, rough plaster | 5 - smooth plaster |
| 3 - concrete | 6 - glass, white paint
on pine |

When selecting the appropriate code for the wall or roof material in the building being specified, it should be remembered that the important parameter indicated by these codes is the relative surface roughness and not the exact type of surface material.

The peak ventilation air flowrate is used as an index for the scheduling of ventilation which is compared with the computed infiltration air flowrates to obtain the heat loss due to direct air exchanges between the building's interior

and exterior. This flowrate need not be limited to only buildings containing forced-air ventilation equipment, since the code considers the opening of windows to cause a ventilation rather than an infiltration air exchange. The peak value input on this card should generally be obtained from either building code specifications of the required ventilation rates for various structural and occupancy classifications, or it should be based upon measured air exchange data (such as a typical number of air changer per hour) for the specified building.

Variables:

I - building type code number

MTW(I) - wall surface material type code

MTR(I) - roof surface material type code

BH(I) - building height (in ft.)

AINFL(I) - peak ventilation air flowrate (in CFM)

Format:	c.c. 1-2	I2	I
	c.c. 5-6	I2	MTW(I)
	c.c. 9-10	I2	MTR(I)
	c.c. 13-19	F7.2	BH(I)
	c.c. 20-29	F10.2	AINFL(I)

20. Building Solar Data, Internal Heating, and
Domestic Hot Water Data Card

This card inputs the building orientation, internal window shading coefficient, wall and roof shading coeffi-

coefficients, wall and roof material solar absorptivities, the nominal maximum rate of non-space-conditioning heat production, and the nominal maximum rate of service hot water consumption for the building specified by its type number code. One card is required for each building type as specified on the Building Type Number Card.

The orientation of the building is measured in degrees clockwise from North, and is referenced to that wall whose normal is closest to North. Thus, if a building has one wall facing north, its orientation angle would be 0° ; one wall facing Northeast would result in an orientation of 45° . If the specified building represents an aggregation of several randomly-oriented units, the reference wall angle should approximate any observed trends in the actual orientations. (It should be noted that the orientation must always lie within the range $0^\circ \leq WA < 90^\circ$, since the building is assumed to be square). For the purposes of computing loads on a per-wall basis, the reference wall is designated as #1, and the walls are numbered clockwise from the North.

The internal window shading coefficient input on this card is, in a sense, a "reciprocal shading coefficient" since it actually indicates a measure of the amount of solar energy incident upon a window which is transmitted and converted to heat within the building. The coefficient is input as a decimal fraction, with 0 indicating full shading and 1.0

indicating no shading. Included in this value should be the effects of such fixtures as double glazing, tinted glass, venetian blinds, drapes, shades, etc. (i.e., anything inside the exposed surface of the window which would modify the solar heating obtained from clear 1/8" single pane glass). Table A.6 contains shading coefficients for a range of typical window configurations, and References 4 and 5 contain more complete listings.

Exterior surface shading coefficients (actually, reciprocal shading coefficients or lighted fractions) are input on this card for each of the four walls of the building and its roof. As is discussed above, the walls are numbered consecutively from 1 to 4, clockwise from the North, and the roof is assigned an equivalent wall index of 5. The exterior shading coefficient for each of these surfaces should provide an estimate of the fraction of that surface, under direct sunlight conditions, which is actually lit by solar radiation. Thus, if the building is immediately adjacent to a larger building abutting its southern wall, the coefficient for wall #3 would be 0; conversely, if the North wall is completely free of shading, even though the sun may never actually shine directly upon it due to its position in the sky, the coefficient for that wall should be specified as 1.0 to indicate that any radiation available to the wall will reach it unimpeded. When aggregating several randomly-oriented build-

ings into a single representative unit, estimates should be made of the net effects of exterior shading upon these buildings and the aggregate data should be used to derive effective wall and roof shading coefficients.

The wall and roof material solar absorptivities are measures of the fraction of the solar radiation incident upon those surfaces which is absorbed and converted to heat within the building. In general, the values specified will depend upon both the color and the composition of the surface. A range of typical absorptivities is listed in Table A.7, which has been extracted from more comprehensive summaries in References 4 and 5.

Also input on this card is a value for the nominal maximum rate of internal building heat generation from all sources not directly associated with space conditioning (e.g., lights, motors, appliances, people). This peak value should be input in kW, and it serves as an index for the scheduling of non-space-conditioning heat generation as a function of building occupancy and intensity of use.

Finally, a measure of the nominal maximum rate of service hot water usage (e.g., showers, wash basins, cooking, etc.) is required to be input in units of BTU/hr. This peak, as are those for ventilation and internal heat generation, is used as an index for an hourly hot water heating demand schedule for the building. Since most tabulations and field measure-

ments of domestic hot water consumption are presented in units of gallons/hour, converting these rates to the data value required on this card necessitates estimates to be made of both the municipal water supply temperature to the building and of the water temperature at the heater outlet to determine the energy demand per unit flow.

Variables:

I - building type code number

WA(I) - building orientation (in degrees from North)

WDSC(I) - window internal shading coefficient (decimal fraction of incident radiation which is transmitted as heat)

FWLIT(I,NN) - fraction of surface NN open to direct solar radiation [NN = 1-4: walls, NN = 5: roof]

WSAB(I) - wall material solar absorptivity (decimal fraction of incident radiation absorbed)

RSAB(I) - roof material solar absorptivity (decimal fraction of incident radiation absorbed)

POL(I) - nominal peak internal heat generation rate from non-space-conditioning sources (in kW)

DHW(I) - nominal peak domestic hot water consumption rate (in BTU/hr)

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Format:	c.c. 1-2	I2	I
	c.c. 3-9	F7.2	WA(I)
	c.c. 10-14	F5.2	WDSC(I)
	c.c. 15-19	F5.2	FWLIT(I,1)
	c.c. 20-24	F5.2	FWLIT(I,2)
	c.c. 25-29	F5.2	FWLIT(I,3)
	c.c. 30-34	F5.2	FWLIT(I,4)
	c.c. 35-39	F5.2	FWLIT(I,5)
	c.c. 40-44	F5.2	WSAB(I)
	c.c. 45-49	F5.2	RSAB(I)
	c.c. 50-58	F9.2	POL(I)
	c.c. 59-69	E11.4	DHW(I)

21. Building External Supply Data Card

This card inputs the number of units of a building type which are not served by the TUS and, of that number, the fraction which have electric resistance heaters and the fraction having heat pumps. One card must be supplied for each of the building types specified on the Building Type Number Card.

Those buildings not supplied with HTW are considered to be part of the TES "external system" and have their energy needs supplied electrically. Because no detailed electrical distribution system analysis is performed by the code, only the total number of buildings and their mode of energy

supply are required for the calculation of the external system electrical demand. It is assumed that all the specified external system buildings have compressive air conditioners. However, the required resistance and heat pump fractions need not sum to 1.0, since the code allows a fraction of the external buildings to be heated from in-house fossil-fired furnaces which present no load to the TES.

Variables:

I - building type code number

NUEX(I) - number of units not connected to TUS

FREXT(I) - fraction of electrically-supplied units
having resistance heat (decimal fraction)

FHPEX(I) - fraction of electrically-supplied units
having heat pumps (decimal fraction)

Format:	c.c. 1-2	I2	I
	c.c. 3-7	I5	NUEX(I)
	c.c. 8-12	F5.2	FREXT(I)
	c.c. 13-17	F5.2	FHPEX(I)

22. Building Type and End-Use Equipment Distribution Card

This card inputs the number of buildings of a given type served by a load center heat exchanger. Also given are the total number of compressive and absorptive air conditioning units and the number of electrical resistance heating units, heat pumps and hot water heating units contained in

these buildings. Since the program reads these cards according to building type within each heat exchanger area, one card must be supplied for each building type for each load center heat exchanger, even if a particular heat exchanger does not supply every type (e.g., if there are 4 secondary loops with 5 heat exchangers per loop and a total of 6 buildings types in the community, a total of $4 \times 5 \times 6 = 120$ Building Type and End-Use Equipment Distribution Cards must be supplied). The order in which these cards should be placed in the data deck is: for the first load center heat exchanger, NTYPE cards should be input consecutively according to the building code numbers defined by the Building Type Number Card; this sequence is then repeated in succession for every load center heat exchanger.

Buildings should be apportioned to the various load center heat exchangers so as to provide a fairly uniform load distribution among the heat exchangers in a given loop and among all the loops in the system. If no buildings of a given type are served by a given heat exchanger, "0" may be specified for the number of buildings on the Building Type and End-Use Equipment Distribution Card, or the card may be left blank.

End-Use equipment should be distributed throughout the system so as to provide an optimum thermal/electric energy utilization efficiency for the community as a whole. The

data given on this card for the numbers of individual heating and cooling units serving a particular building type in a given area of the community is used by the program to distribute the space conditioning loads among the various equipment categories provided. The specific numbers given can be the number of buildings served by a particular equipment type or the total number of individual units of that type in the area being specified. However, the numbers should be specified consistently throughout the system and must present a true indication of the relative equipment distribution in each consumer sector.

Variables:

NU(IX,I) - number of building units of type I served
by heat exchanger IX

NCMP(IX,I) - number of compressive air conditioning
units in buildings of type I for heat
exchanger IX

NABS(IX,I) - number of absorptive air conditioning
units in buildings of type I for heat
exchanger IX

NRES(IX,I) - number of electrical resistance heating
units in buildings of type I for heat
exchanger IX

NHPM(IX,I) - number of heat pumps in buildings of type
I for heat exchanger IX

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NHWS(IX,I) - number of hot water heating units in
buildings of type I for heat exchanger IX

Format:	c.c. 1-5	I5	NU(IX,I)
	c.c. 6-10	I5	NCMP(IX,I)
	c.c. 11-15	I5	NABS(IX,I)
	c.c. 16-20	I5	NRES(IX,I)
	c.c. 21-25	I5	NHPM(IX,I)
	c.c. 26-30	I5	NHWS(IX,I)

23. End-Use Equipment Efficiency Data Card

This card inputs the efficiencies (or coefficients of performance) of the compressive and absorptive air conditioning units, the electrical resistance heating units, heat pumps, and hot water heating units in the system. For the compressive air conditioning units, heat pumps and electrical resistance heating units, this efficiency should be expressed in terms of the rated BTU/hr heating or cooling capacity per BUT/hr equivalent of the required input electrical power. For the absorptive air conditioning and hot water heating units, the efficiency should be expressed in terms of the rated BTU/hr heating or cooling capacity per BTU/hr of the input thermal power. The specified efficiencies should be consistent with the operating characteristics of the various equipment under system design supply temperature and room space conditioning requirements. The nominal heat pump COP should be specified at an ambient air temperature of 32 °F

and a room temperature of 68 °F; nominal compressive and absorptive air conditioning COPs are defined at an air temperature of 90 °F and a room temperature of 75 °F. A non-zero value for the efficiency of each equipment type should be given, even though a given type may not appear anywhere in the system.

Variables:

ECMP - compressive air conditioning unit coefficient of performance (dimensionless)

EABS - absorptive air conditioning unit coefficient of performance (dimensionless)

ERES - electrical resistance heating unit efficiency (dimensionless)

EHPM - heat pump coefficient of performance (dimensionless)

EHWS - hot water heating unit efficiency (dimensionless)

Format:	c.c. 1-5	F5.2	ECMP
	c.c. 6-10	F5.2	EABS
	c.c. 11-15	F5.2	ERES
	c.c. 16-20	F5.2	EHPM
	c.c. 21-25	F5.2	EHWS

24. Case Input Mass Flowrate Scale Factor Card

This card inputs the case input mass flowrate scale factor used to scale the fluid mass flowrates specified on the Nodal Fluid Parameter Information Cards. In general, a

value for this factor other than 1.0 should not be specified unless the only input parameters to be varied between two given simulations are the nodal mass flowrates, which are scaled uniformly throughout the TUS. In this instance, this factor should be the ratio between the desired flowrates and the originally specified values, and the Nodal Fluid Parameter Information Cards need not be re-punched.

Variables:

CSFAC - case input mass flowrate scale factor

Format: c.c. 1-7 F7.4 CSFAC

25. Solar Data Card

On this card are input the latitude of the community being studied, and the solar declination angle, the apparent solar constant, the atmospheric extinction coefficient and the sky diffuse factor for the day on which the simulation is performed. Also input is the hour of the day at which the initial system loads are to be calculated and the steady-state system analysis is to be performed.

The latitude should be input in (positive) degrees north or south of the equator.

The solar declination angle, apparent solar constant, atmospheric extinction coefficient and sky diffuse factor are observed insolation parameters which depend upon the time of year as summarized in Table A.4. The solar declination angle should be input in degrees. The apparent solar constant,

which measures the intensity of a direct solar beam normally incident upon a horizontal surface under clear skies, is input in BTU/hr-ft². The atmospheric extinction coefficient indicates the absorption in the atmosphere of direct solar radiation, and the sky diffuse factor measures the dispersion of the solar beam as it travels through the atmosphere.

The time of day input on this card is the hour at which the initial system calculations are to be performed and is the beginning time of the dynamic analysis. Since all time-dependent data is read sequentially on an hourly basis without specifying the precise time of day with which it is associated, this beginning hour indicator initializes the time clock and is used to assign solar time values to each hourly data point. A continuous 24-hour time clock is employed by the model, with midnight being assigned an hour indicator of 0 and noon an indicator of 12; a simulation covering the 12-hour period between 2 PM and 2 AM, for example, would have 14 as its specified beginning hour and would terminate at hour 2.

Variables:

ALAT - latitude of location (in degrees)

DECL - solar declination angle (in degrees)

ASC - apparent solar constant (in BTU/hr-ft²)

AEC - atmospheric extinction coefficient

SDF - sky diffuse factor

IBHR - beginning hour of simulation period (0-23)

Format:	c.c. 1-5	F5.2	ALAT
	c.c. 6-11	F6.2	DECL
	c.c. 12-16	F5.0	ASC
	c.c. 17-22	F6.3	AEC
	c.c. 23-28	F6.3	SDF
	c.c. 29-31	I3	IBHR

26. Power Plant Rating and Peak Non-Space-Conditioning Electrical Demand Data Card

This card inputs the power plant thermal rating and the peak non-space-conditioning electrical load for the community. The power plant output must be given in MWt and the electrical load in MWe.

The specified power plant thermal output is held constant throughout the simulation and provides the total power input to both the electrical and thermal energy distribution systems. This output power level should be set approximately equal to the average total energy demand for the community over the period of the simulation. Higher outputs will result in a net storage of energy in the reservoir during the simulation; lower outputs will result in a net removal of heat from the reservoir and possible inability to meet the peak energy demands of the community. The program uses the power plant output as primary input to the dynamic system calculations; the heat available to the thermal distribution

system is given by the difference between this constant output and the instantaneous energy demand for electrical power production.

The electrical load specified on this card should be the peak electrical power demand, excluding space conditioning, for the community over the period of the simulation. To eliminate space conditioning effects, the electrical load data specified should be representative of a minimum demand period during the Autumn or Spring, when neither air conditioning nor space heating is required.

Variables:

RTBL - power plant constant total power output (in MWt)

ELBL - peak community electrical load excluding space conditioning (in MWe)

Format:	c.c. 1-10	F10.0	RTBL
	c.c. 11-20	F10.0	ELBL

27. Primary Program Flow Control Code Card

This card inputs the primary program flow control code KODE, which identifies the general type of program execution to be performed according to the following conventions:

KODE=0: Perform building load analysis (if IDES=1)
or perform TUS steady-state convergence
(if IDES=0),

KODE=1: Perform hourly building load summary (if
sequence KODE=0, IDES=1 input previously)
or perform dynamic system analysis, and

KODE=2: Terminate program execution.

In limited cases, KODE may be input more than once for a given computer run to transfer control of program execution from one program option to another. Examples of such sequential operations are:

KODE=0, IDES=1, KODE=1: Computes, adds and distributes building loads at one time instant and computes up to 24 hourly building space conditioning loads,

KODE=0, IDES=0, KODE=1: Steady-state system analysis used to internally initialize dynamic simulation TUS parameters, and

Nesting of several combinations of KODE=0 and IDES=0,1 are also possible to analyze several instantaneous system loading conditions within the same TUS configuration without performing any dynamic energy system analyses.

In general, it is recommended that program execution be terminated following the completion of a dynamic system simulation, since the retention of TUS parameter values from the dynamic calculations could invalidate certain portions of directly continued steady-state or building load analyses.

Variables:

KODE - primary program flow control code (0,1,2)

Format: c.c. 1-3 I3 KODE

28. Building Load Analysis Control Code Card

The building load analysis control code IDES must be input immediately following each specification of KODE=0. As summarized in the description of the Primary Program Flow Control Code Card and in Table A.9,

IDES=0: Perform steady-state TUS convergence and analysis, or

IDES=1: Perform building load analysis and print net building space conditioning demands; aggregate and print initial building loads and distribution, and print initial thermal demands at each load center heat exchanger.

IDES should not be specified following the input of KODE=1 unless the system is re-initialized by reading KODE=0.

Variables:

IDES - building load analysis control code (0,1)

Format: c.c. 1-3 I3 IDES

29. Initial Air Temperature Data Card

This card inputs the ambient air temperature to be used in determining the initial building space conditioning energy demands. If a dynamic simulation is to be performed by using the steady-state system analysis to initialize the TUS parameters, this temperature must be the initial hourly data point for the period being studied (i.e., the temperature at time $t=IBHR$). The temperature must be specified in °F.

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Variables:

TAIR(25) - air temperature at time $t = \text{IBHR}$ (in $^{\circ}\text{F}$)
(the index 25 is reserved by the program
for initial conditions data)

Format: c.c. 1-5 F5.2 TAIR(25)

30. Initial Wind Velocity Data Card

Input on this card is the initial wind velocity,
in mph, for the location at time $t = \text{IBHR}$.

Variables:

WV(25) - wind velocity at time $t = \text{IBHR}$ (in mph)

Format: c.c. 1-5 F5.2 WV(25)

31. Initial Wind Direction Data Card

On this card is input the direction from which the
wind is blowing at time $t = \text{IBHR}$. The direction is measured
in degrees, clockwise from North (e.g., a wind incident from
the Southwest would have a direction angle of 225°).

Variables:

WDIR(25) - wind incidence direction at time $t = \text{IBHR}$
(in degrees from North)

Format: c.c. 1-5 F5.2 WDIR(25)

32. Initial Electric Load Factor Data Card

This card inputs the electric load factor which
multiplies the peak community demand specified on the Power
Plant Rating and Peak Non-Space-Conditioning Electrical

Demand Data Card to determine the non-space conditioning electric load during the steady-state calculations. If a dynamic simulation is to be run using the steady-state sub-routines to initialize the system, this load factor must be the initial hourly data point (i.e., the factor at time $t = \text{IBHR}$) for the period being studied. The factor is dimensionless and merely represents the ratio of the instantaneous system electrical load to the peak load for the period under investigation. (Inputting such a combination of a peak load and load factors allows the simple retention of a given load profile while varying the size of the community to be supplied).

Variables:

ELF(25) - electric load factor (ratio of instantaneous to peak non-space-conditioning electric load) at time $t = \text{IBHR}$

Format: c.c. 1-5 F5.2 ELF(25)

33. Initial Building Room Temperature Data Card

This card inputs the room temperatures, by building type, to be used in determining the building space conditioning loads for the steady-state system calculations. If a dynamic simulation is to be run using the steady-state sub-routines to initialize the system parameters, these temperatures must be the initial hourly data points (i.e., the

temperatures at time $t = \text{IBHR}$) for the period being studied. Each building type is assumed to have a characteristic room temperature throughout all the rooms of that building type in the community. These temperatures are allowed to vary throughout the simulation to correspond to the changing requirements of the people using the buildings. All temperatures must be specified in $^{\circ}\text{F}$. One temperature is required for each of the building types specified on the Building Type Number Card. A maximum of 20 building types is allowed. If more than 10 building types are specified, two cards must be used to input the temperatures.

Variables:

TSB(25,I) - desired room temperature for building type

I at time $t = \text{IBHR}$ (in $^{\circ}\text{F}$) (maximum of $I=20$)

Format: (Card 1)

c.c. 1-7 F7.2 TSB(25,1)

c.c. 8-14 F7.2 TSB(25,2)

 : :

c.c. 64-70 F7.2 TSB(25,10)

(Card 2) (not required if $\text{NTYPE} \leq 10$)

c.c. 1-7 F7.2 TSB(25,11)

c.c. 8-14 F7.2 TSB(25,12)

 : :

 F7.2 TSB(25,NTYPE)

34. Initial Building Use Factor Data Card

On this card are input the occupancy-related building use factors which multiply the peak ventilation air flowrate (from the Building Miscellaneous Data Cards) and the peak non-space-conditioning equipment heat generation rate (from the Building Solar Data, Internal Heating, and Domestic Hot Water Data Cards) to obtain the instantaneous values of these parameters for each building type at time $t = \text{IBHR}$. It is assumed by the code that, in general, ventilation requirements and internal heat generation are functions of building occupancy and intensity of usage. Therefore, these use factors provide a measure of the relative occupancy of each building type and should be given as the ratio of the instantaneous ventilation or internal heating rates to the peaks observed during the simulation period. If more than 10 building types are specified, two cards must be used to input the factors.

Variables:

BUF(25,I) - use factor for building type I at time
 $t = \text{IBHR}$ (decimal fraction of peak use)

Format: (Card 1)

c.c. 1-7	F7.2	BUF(25,1)
c.c. 8-14	F7.2	BUF(25,2)
:	:	:
c.c. 64-70	F7.2	BUF(25,10)

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(card 2) (not required if NTYPE \leq 10)

c.c. 1-7 F7.2 BUF(25,11)

c.c. 8-14 F7.2 BUF(25,12)

 : :

 F7.2 BUF(25,NTYPE)

35. Initial Domestic Hot Water Use Factor Data Card

This card inputs the use factors which multiply the peak domestic hot water demands from the Building Solar Data, Internal Heating, and Domestic Hot Water Data Cards to obtain the instantaneous energy demands for domestic hot water service at time $t = \text{IBHR}$. Although it is correlated with building occupancy, hot water consumption generally follows a different schedule from that specified by the general building use factor and is therefore allowed to vary independently from the building ventilation and internal heat generation rates determined by BUF. If a building has no domestic hot water consumption (e.g., a warehouse or small commercial building), its use factor should simply be input as 0 or left blank on this card. If more than 10 building types are specified, two cards must be used to input the factors.

Variables:

WUF(25,I) - domestic hot water use factor for building type I at time $t = \text{IBHR}$ (decimal fraction of peak use)

Format: (card 1)

c.c. 1-7	F7.2	WUF(25,1)
c.c. 8-14	F7.2	WUF(25,2)
:	:	:
c.c. 64-70	F7.2	WUF(25,10)
(card 2) (not required if NTYPE \leq 10)		
c.c. 1-7	F7.2	WUF(25,11)
c.c. 8-14	F7.2	WUF(25,12)
:	:	:
.	F7.2	WUF(25,NTYPE)

36. Hourly Data Point Number Card

This card inputs the number of hourly data points to be used in the dynamic system simulation. The first hourly data point is assumed to be given at time $t = \text{IBHR} + 1$. Therefore, the number specified on this card must not include the initial data values used by the steady-state initialization subroutines, and it should correspond to the total duration of the simulation in hours. For example, a 6-hour simulation would require 6 data points in addition to the initialization values, and "6" would be specified on this card. Since the maximum single simulation period is 24 hours, a maximum of 24 hourly data points per simulation is allowed.

Variables:

NTEMP - number of hourly data points in simulation
(maximum of 24)

Format: c.c. 1-3 I3 NTEMP

37. Hourly Air Temperature Data Card

This card inputs the hourly external air temperature values to be used in determining the building space conditioning loads during the dynamic system simulation. The first value specified should be the air temperature at time $t = \text{IBHR} + 1$ (i.e., one hour into the simulation). One temperature value must be given for each of the data points specified on the Hourly Data Point Number Card. The program uses a linear interpolation routine to determine intermediate temperatures for each simulation time step. Therefore, the specified temperatures should accurately reflect the actual air temperature profile for the time period being studied. The temperatures should be listed consecutively on this card according to the given input format; a maximum of 12 values per card and a maximum of 2 cards per simulation (i.e., a maximum of 24 hourly data points) is allowed. The temperatures must be given in units of °F.

Variables:

TAIR(I) - external air temperature at time I hours
into the simulation (maximum of I = 24
values). (in °F)

Format: (card 1)

c.c. 1-5 F5.2 TAIR(1)

c.c. 6-10 F5.2 TAIR(2)

 . . .

 . . .

 . . .

c.c. 56-60 F5.2 TAIR(12)

(card 2) (not required if NTEMP \leq 12)

c.c. 1-5 F5.2 TAIR(13)

c.c. 6-10 F5.2 TAIR(14)

 . . .

 . . .

 F5.2 TAIR(NTEMP)

(Max of NTEMP = 24)

38. Hourly Wind Velocity Data Card

This card inputs the hourly wind velocities for the simulation period. The first value specified is assumed to obtain at time $t = \text{IBHR} + 1$ (i.e., one hour into the simulation), and the total number of data points must correspond to the number of simulation hours specified on the Hourly Data Point Number Card. Velocities should be in units of miles/hr. If the simulation is to span more than 12 hours, two data cards are required as shown below.

Variables:

WV(I) - wind velocity at time I hours into the simulation (maximum of I=24 values) (in mph)

Format: (card 1)

c.c. 1-5 F5.2 WV(1)

c.c. 6-10 F5.2 WV(2)

: : :

c.c. 56-60 F5.2 WV(12)

(card 2) (not required if NTEMP \leq 12)

c.c. 1-5 F5.2 WV(13)

c.c. 6-10 F5.2 WV(14)

: : :

. F5.2 WV(NTEMP)

39. Hourly Wind Direction Data Card

On this card are input the wind directions for each hour of the simulation period. The first hourly data point is defined at time $t = \text{IBRH} + 1$ (i.e., one hour into the simulation), and the total number of values specified should correspond to the number of simulation hours input on the Hourly Data Point Number Card. The wind incidence directions should be given in degrees, measured clockwise from North. If the simulation is to cover more than 12 hours, two data cards are required.

Variables:

WDIR(I) - wind incidence direction at time I hours
into the simulation (in degrees from North)

Format: (card 1)

c.c. 1-6 F6.2 WDIR(1)

c.c. 7-12 F6.2 WDIR(2)

 : :

c.c. 67-72 F6.2 WDIR(12)

(card 2) (not required if $NTEMP \leq 12$)

c.c. 1-6 F6.2 WDIR(13)

c.c. 7-12 F6.2 WDIR(14)

 : :

 F6.2 WDIR(NTEMP)

40. Hourly Electric Load Factor Data Card

This card inputs the hourly electric load factors which multiply the peak community load specified on the Power Plant Rating and Peak Non-Space-Conditioning Electrical Demand Data Card to determine the non-space conditioning electric loads during the dynamic system simulation. The first value specified should be the load factor at time $t = IBHR+1$ (i.e., one hour into the simulation). One value must be given for each of the data points specified on the Hourly Data Point Number Card. The program uses a linear interpolation routine to determine intermediate loads for each simulation time step. Therefore, the specified load factors should accurately reflect the actual community electrical load profile for the time period being studied. The factors should be listed consecutively on this card according to the given

input format; a maximum of 12 values per card and a maximum of 2 cards per simulation (i.e., a maximum of 24 hourly data points) is allowed.

Variables:

ELF(I) - electrical load factor (ratio of instantaneous total non-space-conditioning electric load to peak for period) at time I hours into the simulation (maximum of I=24 values).

Format: (card 1)

c.c. 1-5	F5.2	ELF(1)
----------	------	--------

c.c. 6-10	F5.2	ELF(2)
-----------	------	--------

.	.	.
---	---	---

.	.	.
---	---	---

c.c. 56-60	F5.2	ELF(12)
------------	------	---------

(card 2) (not required if NTEMP \leq 12)

c.c. 1-5	F5.2	ELF(13)
----------	------	---------

c.c. 6-10	F5.2	ELF(14)
-----------	------	---------

.	.	.
---	---	---

.	.	.
---	---	---

.	F5.2	ELF(NTEMP)
---	------	------------

(Max. of NTEMP=24)

41. Hourly Building Room Temperature Data Cards

This card inputs the room temperatures, by building type, to be used in determining the building space conditioning

loads for the dynamic system simulation. Each building type is assumed to have a characteristic room temperature which must be maintained by the space heating/cooling systems throughout all the rooms of that building type in the community. These temperatures are allowed to vary on an hourly basis to correspond to the changing requirements of the people using the buildings. (e.g., Business Offices need not be fully heated during unoccupied periods). The program uses a linear interpolation routine to determine intermediate temperatures for each simulation time step. Therefore, the specified temperatures should accurately reflect the actual desired room temperature variations for the time period being studied. All temperatures must be specified in °F. One temperature per card is required for each of the building types specified on the Building Type Number Card; a maximum of 20 building types is allowed, and if the number of types specified exceeds 10, two data cards must be input per simulation hour. One card (or pair of cards, if NTYPE > 10) must be supplied for each of the hourly data points specified on the Hourly Data Point Number Card, with the first card(s) in the set corresponding to time $t = \text{IBHR} + 1$ (one hour into the simulation). A maximum of 24 data points per building type is allowed.

Variables:

TSB(I,NN) - internal room temperature at time I hours
into the simulation for building type NN
(maximum of I=24, NN=20) (in °F)

Format: (card 1)

c.c. 1-7	F7.2	TSB(1,1)
c.c. 8-14	F7.2	TSB(1,2)
:	:	:
c.c. 64-70	F7.2	TSB(1,10)

(card 2, if NTYPE > 10)

c.c. 1-7	F7.2	TSB(1,11)
c.c. 8-14	F7.2	TSB(1,12)
:	:	:
.	F7.2	TSB(1,NTYPE)

(card 2, if NTYPE ≤ 10) (card 3, if NTYPE > 10)

c.c. 1-7	F7.2	TSB(2,1)
c.c. 8-14	F7.2	TSB(2,2)
:	:	:
c.c. 64-70	F7.2	TSB(2,10)

To NTEMP (maximum of 24) cards or pairs of cards.

42. Hourly Building Use Factor Data Cards

This card inputs, for each building type specified on the Building Type Number Card, the building use factor which multiplies both the peak ventilation and the peak internal heat generation rates to determine the instantaneous

hourly values of these parameters. If more than 10 building types are specified, two cards must be input per simulation hour. The first card, or pair of cards, in the data set should contain data observed at time $t = IBHR+1$ (i.e., one hour into the simulation), and the total number of data points per building type should correspond to the number of hours specified on the Hourly Data Point Number Card. If the observed ventilation and internal heating schedules for a given building type differ significantly, attempts should be made to adjust the specified peak values of each so that the net effects of the single schedule will approximate the measured behavior.

Variables:

BUF(I,NN) - building use factor at time I hours into the simulation for building type NN (maximum of $I=24$, $NN=20$) (decimal fraction of peak ventilation and internal heating rates)

Format: (card 1)

c.c. 1-7	F7.2	BUF(1,1)
c.c. 8-14	F7.2	BUF(1,2)
:	:	:
c.c. 64-70	F7.2	BUF(1,10)

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(card 2, if NTYPE > 10)

c.c. 1-7	F7.2	BUF(1,11)
c.c. 8-14	F7.2	BUF(1,12)
:	:	:
.	F7.2	BUF(1,NTYPE)

(card 2, if NTYPE ≤ 10) (card 3, if NTYPE > 10)

c.c. 1-7	F7.2	BUF(2,1)
c.c. 8-14	F7.2	BUF(2,2)
:	:	:
c.c. 64-70	F7.2	BUF(2,10)

To NTEMP (maximum of 24) cards or pairs of cards.

43. Hourly Domestic Hot Water Use Factor Data Cards

On this card are input, for each building type specified on the Building Type Number Card, the domestic hot water use factors which multiply the peak water consumption rates on the Building Solar Data, Internal Heating, and Domestic Hot Water Data Cards to obtain the hourly hot water service energy demands. If the number of specified building types exceeds 10, two cards must be supplied per simulation hour. The first set of data points should be specified at time $t = \text{IBHR} + 1$ (one hour into the simulation), and a set of use factors should be input for each hour specified on the Hourly Data Point Number Card.

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Variables:

WUF(I,NN) - domestic hot water use factor at time I
hours into the simulation for building
type NN (maximum of I=24, NN=20) (decimal
fraction of peak use rate)

Format: (card 1)

c.c. 1-7	F7.2	WUF(1,1)
c.c. 8-14	F7.2	WUF(1,2)
:	:	:
c.c. 64-70	F7.2	WUF(1,10)

(card 2, if NTYPE > 10)

c.c. 1-7	F7.2	WUF(1,11)
c.c. 8-14	F7.2	WUF(1,12)
:	:	:
.	F7.2	WUF(1,NTYPE)

(card 2, if NTYPE \leq 10) (card 3, if NTYPE > 10)

c.c. 1-7	F7.2	WUF(2,1)
c.c. 8-14	F7.2	WUF(2,2)
:	:	:
c.c. 64-70	F7.2	WUF(2,10)

To NTEMP (maximum of 24) cards or pairs of cards.

A.5.2 Sample 24-Hour Input Data Listing

To familiarize the user with the composition of the data deck, a complete listing of the input data required for a sample 24-hour TES simulation is given below.

The specific input data presented models a thermal energy distribution system consisting of a single primary HTW loop and three secondary distribution loops - the first serving three, the second serving four, and the third serving five load center heat exchangers. The primary loop contains approximately 10 miles of nominal 18" O.D. pipe, while the secondary loops each have 12" O.D. pipe. All heat exchangers contain 1" O.D. tubes having 1" I.D. interstitial flow channels. All circulation pumps are located in the return lines to the loop supply heat exchangers. The system is supplied from the TUS supply heat exchanger at a constant water temperature of 380 °F; consumer end-use equipment is supplied at nominal temperatures of 220 °F and 240 °F, depending upon the type of equipment, the location, and the load to be served.

The consumer sectors contain a total of eleven different building types, representing a community with a resident population of approximately 50,000. The buildings are distributed throughout the community in load centers based upon their general heating and cooling requirements. Also taken into consideration in this distribution are community power plant siting restrictions, with residential areas being located

furthest from the plant site and low constant population industrial sectors situated at a minimum radius of approximately three miles from the station. End-use equipment is distributed throughout the community following practices expected to yield an optimum thermal/electrical energy demand ratio affording a minimum required power plant installed capacity. Approximately 75% of the total energy demands of the community are supplied through the TUS.

The given air temperature data corresponds to a relatively severe winter day at Fayetteville, North Carolina. The non-space-conditioning electrical load schedule was taken from demand data for a minimum space conditioning day at Fort Bragg, North Carolina, and the magnitude of the average load was scaled to match the model community size. To illustrate the effects of weather variations during the period, building room temperature requirements are held constant for each building type. General building usage and domestic hot water consumption schedules follow observed conditions throughout typical 24-hour building occupancy cycles.

The "card type" listing shown below refers to the numerical designations of the various input data card descriptions presented in Section A.5.1. These numbers do not appear on any of the actual data cards and are given here merely as a reference for the user to facilitate identification of the

required card formats and input variables. As a reference for data position on each card, the "7" shown on the first numerical data card appears in column 3. All data up to and including the first Primary Program Flow Control Code Card (type 27) is required for every run. However, data following this card, and certain parameter values specified in the preceding data sets, may be modified according to the specific program option to be executed as summarized in the following sub-sections. It is recommended that the data format presented here (i.e., use of the steady-state sub-routines to initialize the dynamic system calculations - a sequence of $KODE=0$, $IDES=0$, $KODE=1$) be used in all dynamic simulations.

SAMPLE INPUT DATA DECK LISTING

SAMPLE 24-HOUR TFS SIMULATION
WINTER DAY. SOUTHEASTERN U.S.

7	1	0	0	0	1.406	3.04F04	1.520F04	
	1	658E06			380.	0.	1.067	54.47 0.35
	2	0	1	0	0.070	8.00F01	1.346E06	
	1	658F06			0.	0.	1.056	55.22 0.37
	3	0	0	0	1.406	4.00F02	2.000E02	0.42
	1	658F06			0.	0.	1.035	56.65
	4	0	2	0	0.070	8.00F01	2.420E06	
	1	658E06			0.	0.	1.076	57.62 0.47
	5	0	0	0	1.406	9.61F03	4.805E03	
	1	658E06			0.	0.	1.015	58.51 0.57
	6	0	3	0	0.070	8.00F01	6.397E06	
	1	658E06			0.	0.	1.005	60.13 0.74
	7	0	0	1	1.406	2.08F04	6.047F04	
	1	658F06			0.	0.	1.000	61.20 1.06
3	6	3						
	1	0	0	0	0.995	9.24F03	4.620F03	
	3	200E05			0.	0.	1.056	55.22 0.37
	2	1	4	0	0.070	8.00F01	9.199F05	
	1	435E05			0.	0.	1.010	59.37 0.63
	3	1	5	0	0.070	8.00F01	5.941E05	
	9	305F04			0.	0.	1.010	59.37 0.63
	4	1	6	0	0.070	8.00F01	5.941E05	
	8	344F04			0.	0.	1.010	59.37 0.63
	5	0	0	2	0.995	9.24F03	2.514E04	
	3	200E05			0.	0.	0.998	62.00 1.65
	6	0	1	0	0.083	8.00F01	1.346E06	

Card
Type
1 1 2 5

Card Type	Count
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1
17	1
18	1
19	1
20	1
21	1
22	1
23	1
24	1
25	1
26	1
27	1
28	1
29	1
30	1
31	1
32	1
33	1
34	1
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36	1
37	1
38	1
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82	1
83	1
84	1
85	1
86	1
87	1
88	1
89	1
90	1
91	1
92	1
93	1
94	1
95	1
96	1
97	1
98	1
99	1
100	1

2 2 0 2 0 0 2

13	0	13	0	0	13
10	0	10	0	0	10
3	0	3	0	0	3
10	0	10	0	0	10
9	0	9	0	0	9
30	0	30	0	0	30
18	0	18	0	0	18
1	0	1	0	0	1
6	0	6	0	0	6
2	0	1	0	0	1

76	0	76	0	76
76	0	76	0	76

(The following are the names of the people who were interviewed for this study.)

Card Type	Card No.	Card Name	Card Address	Card City	Card State	Card Zip	Card Phone	Card Fax	Card E-mail	Card Web	Card Notes
1	1001	John Doe	123 Main St	New York	NY	10001	212-555-1234	212-555-5678	john.doe@company.com	http://www.johndoe.com	
2	1002	Jane Smith	456 Elm St	Los Angeles	CA	90001	310-555-2345	310-555-6789	jane.smith@company.com	http://www.janesmith.com	
3	1003	Bob Johnson	789 Oak St	Chicago	IL	60601	312-555-3456	312-555-7890	bob.johnson@company.com	http://www.bobjohnson.com	
4	1004	Alice Brown	101 Pine St	San Francisco	CA	94101	415-555-4567	415-555-8901	alice.brown@company.com	http://www.alicebrown.com	
5	1005	Charlie Davis	202 Maple St	Seattle	WA	98101	206-555-5678	206-555-9012	charlie.davis@company.com	http://www.charliedavis.com	
6	1006	Diana Prince	303 Cedar St	Portland	OR	97201	503-555-6789	503-555-0123	diana.prince@company.com	http://www.dianaprince.com	
7	1007	Frank Miller	404 Birch St	Denver	CO	80201	303-555-7890	303-555-1234	frank.miller@company.com	http://www.frankmiller.com	
8	1008	Grace Wilson	505 Spruce St	Phoenix	AZ	85001	602-555-8901	602-555-2345	grace.wilson@company.com	http://www.gracewilson.com	
9	1009	Henry Taylor	606 Ash St	San Diego	CA	92101	619-555-9012	619-555-3456	henry.taylor@company.com	http://www.henrytaylor.com	
10	1010	Ivy Green	707 Willow St	San Jose	CA	95101	408-555-0123	408-555-4567	ivy.green@company.com	http://www.ivygreen.com	
11	1011	Jack White	808 Hickory St	San Antonio	TX	78201	214-555-1234	214-555-5678	jack.white@company.com	http://www.jackwhite.com	
12	1012	Karen Black	909 Walnut St	San Jose	CA	95101	408-555-2345	408-555-6789	karen.black@company.com	http://www.karenblack.com	
13	1013	Leo Clark	1010 Elm St	San Jose	CA	95101	408-555-3456	408-555-7890	leo.clark@company.com	http://www.leoclark.com	
14	1014	Mia Evans	1111 Oak St	San Jose	CA	95101	408-555-4567	408-555-8901	mia.evans@company.com	http://www.miaevans.com	
15	1015	Noah Adams	1212 Pine St	San Jose	CA	95101	408-555-5678	408-555-9012	noah.adams@company.com	http://www.noahadams.com	
16	1016	Olivia Baker	1313 Maple St	San Jose	CA	95101	408-555-6789	408-555-0123	olivia.baker@company.com	http://www.oliviabaker.com	
17	1017	Peter King	1414 Birch St	San Jose	CA	95101	408-555-7890	408-555-1234	peter.king@company.com	http://www.peterking.com	
18	1018	Quinn Lee	1515 Cedar St	San Jose	CA	95101	408-555-8901	408-555-2345	quinn.lee@company.com	http://www.quinnlee.com	
19	1019	Rachel Hall	1616 Spruce St	San Jose	CA	95101	408-555-9012	408-555-3456	rachel.hall@company.com	http://www.rachelhall.com	
20	1020	Sammy Young	1717 Ash St	San Jose	CA	95101	408-555-0123	408-555-4567	sammy.young@company.com	http://www.sammyyoung.com	
21	1021	Tina King	1818 Willow St	San Jose	CA	95101	408-555-1234	408-555-5678	tina.king@company.com	http://www.tinaking.com	
22	1022	Uma Green	1919 Hickory St	San Jose	CA	95101	408-555-2345	408-555-6789	uma.green@company.com	http://www.umagreen.com	
23	1023	Victor White	2020 Walnut St	San Jose	CA	95101	408-555-3456	408-555-7890	victor.white@company.com	http://www.victorwhite.com	
24	1024	Wendy Black	2121 Elm St	San Jose	CA	95101	408-555-4567	408-555-8901	wendy.black@company.com	http://www.wendyblack.com	
25	1025	Xavier Clark	2222 Oak St	San Jose	CA	95101	408-555-5678	408-555-9012	xavier.clark@company.com	http://www.xavierclark.com	
26	1026	Yara Evans	2323 Pine St	San Jose	CA	95101	408-555-6789	408-555-0123	yara.evans@company.com	http://www.yaraevans.com	
27	1027	Zoe Adams	2424 Maple St	San Jose	CA	95101	408-555-7890	408-555-1234	zoe.adams@company.com	http://www.zoeadams.com	
28	1028	Adam Baker	2525 Birch St	San Jose	CA	95101	408-555-8901	408-555-2345	adam.baker@company.com	http://www.adambaker.com	
29	1029	Bella King	2626 Cedar St	San Jose	CA	95101	408-555-9012	408-555-3456	bella.king@company.com	http://www.bellaking.com	

1	0	1	0	1
1	0	1	0	1

166 0 166 0 166

1 0 1 0 0 1

2.0	0.75	1.0	2.4	1.0
1.00				
35.	-20.	300.	.142	.058 0
	150.		35.	

68.	72.	72.	72.	74.	65.	70.	70.	65.	68.
70.	.81	.81	.81	.53	.10	.15	.05	.15	.20
.20	.17	.17	.17	.53					.33

[illegible]

188.

Card
Type
43
43
43
43
43
43
27

.26
.37
.33

.59
.56
.53

.15
.13
.17

.15
.11
.17

.15
.13
.17

.26
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.37
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.33
.33

A.5.3 Input Data Modifications

A.5.3.1 Building Energy Demands

When performing only the single time instant building load analysis (KODE=0, IDES=1, KODE=2), it is possible to eliminate many of the parameter specifications on the cards describing the TUS(types 5 and 6), since the only information required is the general TUS piping configuration and the locations of the load center heat exchangers. Thus, all fluid flowrates, fluid parameters, and nodal dimensions may be omitted, although it may be desirable to input non-zero dummy values for these parameters to eliminate the possibility of computational overflow errors occurring during the transition from the single time analysis to an hourly load analysis. The consumer fluid supply and return temperatures and the nodal fluid specific heats must be specified if a complete analysis is desired, since the initial load center heat exchanger fluid mass flowrates are computed at the same time the load distribution is printed. All TUS nodal cards must be input, along with their location and type codes, to facilitate heat exchanger identification by the load aggregation section of the program. The number of tubes in each heat exchanger need not be specified (card type 8), but its supply-and demand-side node location codes must be supplied. Initial conditions at the reservoir and on the power plant side of the TUS supply heat exchanger are unnecessary, but

dummy values should be input to prevent possible overflows during the initialization calculations. All building parameter specifications and all building distribution data must be supplied to every program run option. Finally, for single time analyses, all initial system data shown in the sample listing between IDES=0 (card type 28) and KODE=1 (card type 27) must be input following IDES=1 to supply the load calculation subroutines with appropriate weather and building requirements specifications. (Of course, KODE=2 would then replace KODE=1 following card type 35, and no further data would be required).

Extension of the single time instant building load analysis to an hourly analysis without performing any TUS calculations requires non-zero (and non-equal) values to be supplied for the consumer fluid supply and return temperatures and non-zero values for the load center heat exchanger fluid specific heats to avoid overflows during the calculation period between the two option executions. Following specification of KODE=1 after the initial weather data and building conditions are input, data must be provided for each hour of the analysis desired. (These hourly data values need not be consistent with continuous functions for a specified time period, since the demands are computed independently at each hourly interval).

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MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF NUCLEAR--ETC F/G 9/2
TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND TOTAL--ETC(U)
AUG 76 J W STETKAR, M W GOLAY

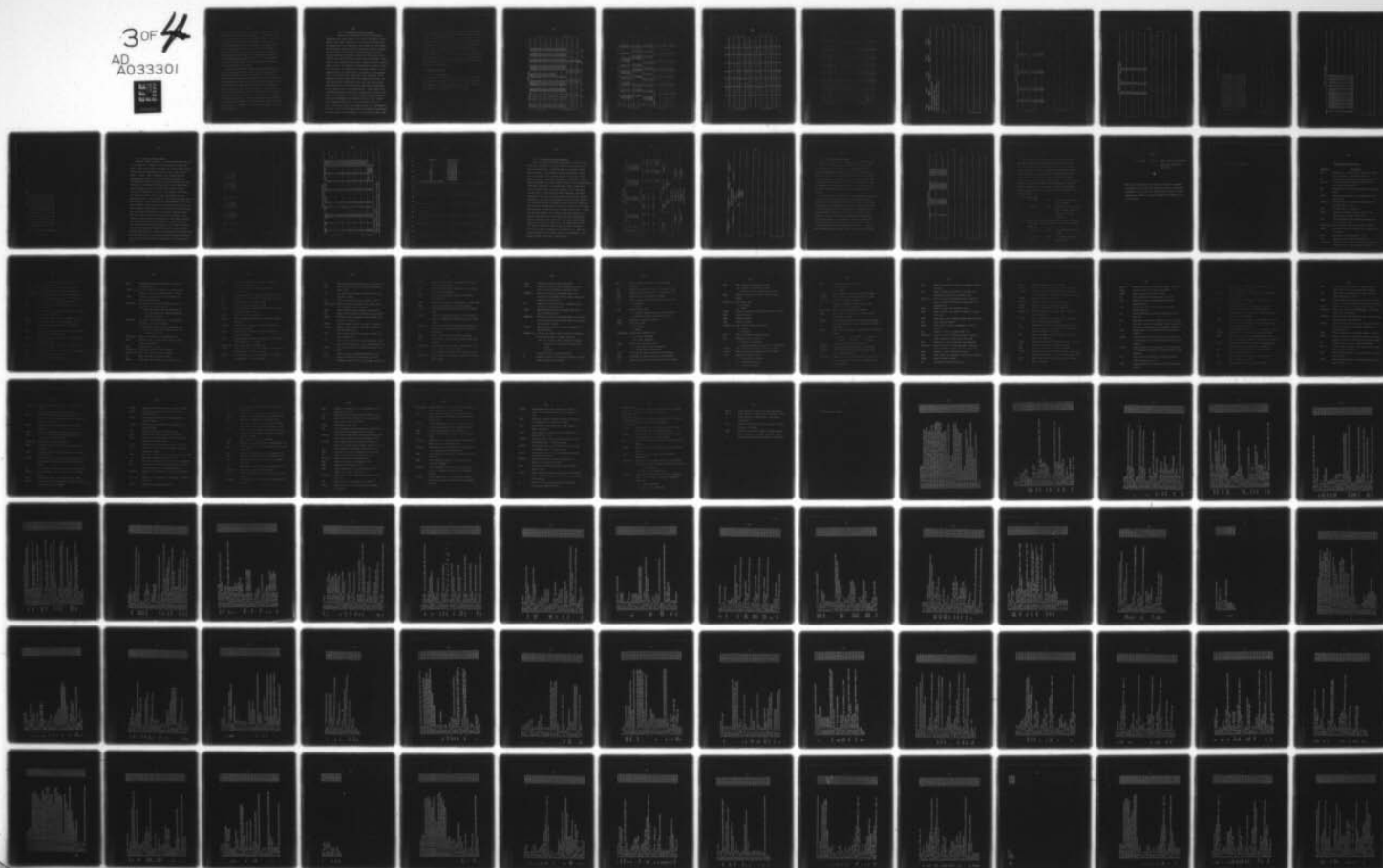
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dummy values should be input to prevent possible overflows during the initialization calculations. All building parameter specifications and all building distribution data must be supplied to every program run option. Finally, for single time analyses, all initial system data shown in the sample listing between IDES=0 (card type 28) and KODE=1 (card type 27) must be input following IDES=1 to supply the load calculation subroutines with appropriate weather and building requirements specifications. (Of course, KODE=2 would then replace KODE=1 following card type 35, and no further data would be required).

Extension of the single time instant building load analysis to an hourly analysis without performing any TUS calculations requires non-zero (and non-equal) values to be supplied for the consumer fluid supply and return temperatures and non-zero values for the load center heat exchanger fluid specific heats to avoid overflows during the calculation period between the two option executions. Following specification of KODE=1 after the initial weather data and building conditions are input, data must be provided for each hour of the analysis desired. (These hourly data values need not be consistent with continuous functions for a specified time period, since the demands are computed independently at each hourly interval).

A.5.3.2 Steady-State System Analysis

Since the steady-state TUS analysis performs essentially the same computations as does the dynamic system analysis (but under steady-state energy and momentum transfer conditions), the input data requirements for the steady-state analysis program execution option are exactly the same as those shown for the dynamic system analysis, with the single exception that $KODE=2$ is input for the second value of $KODE$ (card type 27) and no hourly data is required. Estimates of the secondary loop fluid flowrates should be approximately equal to the expected converged system values to minimize the number of steady-state iterations required. As is demonstrated by the sample data, all secondary loop temperatures, all consumer-side load center heat exchanger fluid flowrates, and all primary HTW loop temperatures except for the fixed supply temperature at the loop inlet may be left unspecified with no adverse effects upon system convergence or the overall cost of the calculations. Since typical TUS configurations may be expected to converge well within 1 CPU-minute of computing time if the estimated initial conditions are at all reasonable (see Table A.10), use of the steady-state system analysis with a specified upper limit of 1 minute for the CPU time can provide a means for verifying the validity of all but the hourly input data directly associated with the dynamic system analysis. Any mis-punched data cards

or input parameters inconsistent with the code assumptions will almost invariably result in generation of an internal computer system data format error, the calculation of converged nodal parameters significantly different from expected conditions, or, in the worst case, non-convergence of the system with no diagnostic output produced. In any event, however, these errors will be identified prior to the initiation of the long and costly dynamic analyses, and will thus be more easily traced to their precise input data source with less expense and frustration than if discovered well into the simulation.

A.6 TDIST Output Data

A.6.1 Input Summary

For every program execution, the first set of output data supplied is a complete summary of the input data for that computer run. The following is the output summary of the sample input data listed in Section A.5.2.

INPUT SUPPLY												***OUTPUT SUPPLY***											
MODE	EXCH	TER	IPMP	DIA	LONG	MASS	AU	CAP	THW	TAMB	DTINE												
1	1	1	0	1-00A0	0-35CUP+05	0-16AUF+07	0-15AUF+05	1-0A70	56-70	0-30													
1	1	2	0	0-0700	C-ACCUF+01	0-16AUF+07	0-13AUF+07	1-0560	55-220	0-370													
1	1	3	0	0-1-00A0	C-ACCUF+01	0-16AUF+07	0-2310F+03	1-0350	56-660	0-420													
1	1	4	0	0-0700	C-ACCUF+02	0-16AUF+07	0-2420F+07	1-0760	57-620	0-570													
1	1	5	0	0-1-00A0	C-ACCUF+02	0-16AUF+07	0-48AUF+04	1-0150	58-510	0-570													
1	1	6	0	0-0700	C-ACCUF+03	0-16AUF+07	0-63AUF+07	1-0050	60-130	0-740													
1	1	7	0	0-1-00A0	C-ACCUF+03	0-16AUF+07	0-60AUF+05	1-0000	61-200	1-060													
1	1	8	0	0-0700	C-ACCUF+04	0-16AUF+07	0-6620F+04	1-0560	55-220	0-370													
1	1	9	0	0-1-00A0	C-ACCUF+04	0-16AUF+07	0-31AUF+06	1-0100	59-370	0-630													
1	1	10	0	0-0700	C-ACCUF+05	0-16AUF+07	0-59AUF+06	1-0100	59-370	0-630													
1	1	11	0	0-1-00A0	C-ACCUF+05	0-16AUF+07	0-59AUF+05	0-99A0	62-010	1-650													
1	1	12	0	0-0700	C-ACCUF+06	0-16AUF+07	0-25AUF+05	0-99A0	62-010	1-650													
1	1	13	0	0-1-00A0	C-ACCUF+06	0-16AUF+07	0-25AUF+06	0-99A0	62-010	1-650													
1	1	14	0	0-0700	C-ACCUF+07	0-16AUF+07	0-56AUF+06	1-0350	60-130	0-740													
1	1	15	0	0-1-00A0	C-ACCUF+07	0-16AUF+07	0-13AUF+06	1-0350	60-130	0-740													
1	1	16	0	0-0700	C-ACCUF+08	0-16AUF+07	0-15AUF+06	1-0350	60-130	0-740													
1	1	17	0	0-1-00A0	C-ACCUF+08	0-16AUF+07	0-17AUF+06	1-0350	60-130	0-740													
1	1	18	0	0-0700	C-ACCUF+09	0-16AUF+07	0-24AUF+06	1-0350	60-130	0-740													
1	1	19	0	0-1-00A0	C-ACCUF+09	0-16AUF+07	0-24AUF+07	1-0350	60-130	0-740													
1	1	20	0	0-0700	C-ACCUF+10	0-16AUF+07	0-55AUF+06	1-0350	60-130	0-740													
1	1	21	0	0-1-00A0	C-ACCUF+10	0-16AUF+07	0-55AUF+07	1-0350	60-130	0-740													
1	1	22	0	0-0700	C-ACCUF+11	0-16AUF+07	0-27AUF+06	1-0350	60-130	0-740													
1	1	23	0	0-1-00A0	C-ACCUF+11	0-16AUF+07	0-27AUF+07	1-0350	60-130	0-740													
1	1	24	0	0-0700	C-ACCUF+12	0-16AUF+07	0-44AUF+06	1-0350	60-130	0-740													
1	1	25	0	0-1-00A0	C-ACCUF+12	0-16AUF+07	0-44AUF+07	1-0350	60-130	0-740													
1	1	26	0	0-0700	C-ACCUF+13	0-16AUF+07	0-54AUF+06	1-0350	60-130	0-740													
1	1	27	0	0-1-00A0	C-ACCUF+13	0-16AUF+07	0-54AUF+07	1-0350	60-130	0-740													
1	1	28	0	0-0700	C-ACCUF+14	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	29	0	0-1-00A0	C-ACCUF+14	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	30	0	0-0700	C-ACCUF+15	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	31	0	0-1-00A0	C-ACCUF+15	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	32	0	0-0700	C-ACCUF+16	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	33	0	0-1-00A0	C-ACCUF+16	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	34	0	0-0700	C-ACCUF+17	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	35	0	0-1-00A0	C-ACCUF+17	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	36	0	0-0700	C-ACCUF+18	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	37	0	0-1-00A0	C-ACCUF+18	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	38	0	0-0700	C-ACCUF+19	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	39	0	0-1-00A0	C-ACCUF+19	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	40	0	0-0700	C-ACCUF+20	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	41	0	0-1-00A0	C-ACCUF+20	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	42	0	0-0700	C-ACCUF+21	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	43	0	0-1-00A0	C-ACCUF+21	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	44	0	0-0700	C-ACCUF+22	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	45	0	0-1-00A0	C-ACCUF+22	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	46	0	0-0700	C-ACCUF+23	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	47	0	0-1-00A0	C-ACCUF+23	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	48	0	0-0700	C-ACCUF+24	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	49	0	0-1-00A0	C-ACCUF+24	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	50	0	0-0700	C-ACCUF+25	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	51	0	0-1-00A0	C-ACCUF+25	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	52	0	0-0700	C-ACCUF+26	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	53	0	0-1-00A0	C-ACCUF+26	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	54	0	0-0700	C-ACCUF+27	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	55	0	0-1-00A0	C-ACCUF+27	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	56	0	0-0700	C-ACCUF+28	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	57	0	0-1-00A0	C-ACCUF+28	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	58	0	0-0700	C-ACCUF+29	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	59	0	0-1-00A0	C-ACCUF+29	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	60	0	0-0700	C-ACCUF+30	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	61	0	0-1-00A0	C-ACCUF+30	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	62	0	0-0700	C-ACCUF+31	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	63	0	0-1-00A0	C-ACCUF+31	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	64	0	0-0700	C-ACCUF+32	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	65	0	0-1-00A0	C-ACCUF+32	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	66	0	0-0700	C-ACCUF+33	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	67	0	0-1-00A0	C-ACCUF+33	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	68	0	0-0700	C-ACCUF+34	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	69	0	0-1-00A0	C-ACCUF+34	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	70	0	0-0700	C-ACCUF+35	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	71	0	0-1-00A0	C-ACCUF+35	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	72	0	0-0700	C-ACCUF+36	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	73	0	0-1-00A0	C-ACCUF+36	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	74	0	0-0700	C-ACCUF+37	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	75	0	0-1-00A0	C-ACCUF+37	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	76	0	0-0700	C-ACCUF+38	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	77	0	0-1-00A0	C-ACCUF+38	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	78	0	0-0700	C-ACCUF+39	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	79	0	0-1-00A0	C-ACCUF+39	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	80	0	0-0700	C-ACCUF+40	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	81	0	0-1-00A0	C-ACCUF+40	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	82	0	0-0700	C-ACCUF+41	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	83	0	0-1-00A0	C-ACCUF+41	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	84	0	0-0700	C-ACCUF+42	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	85	0	0-1-00A0	C-ACCUF+42	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	86	0	0-0700	C-ACCUF+43	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	87	0	0-1-00A0	C-ACCUF+43	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	88	0	0-0700	C-ACCUF+44	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	89	0	0-1-00A0	C-ACCUF+44	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	90	0	0-0700	C-ACCUF+45	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	91	0	0-1-00A0	C-ACCUF+45	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	92	0	0-0700	C-ACCUF+46	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	93	0	0-1-00A0	C-ACCUF+46	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	94	0	0-0700	C-ACCUF+47	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	95	0	0-1-00A0	C-ACCUF+47	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	96	0	0-0700	C-ACCUF+48	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	97	0	0-1-00A0	C-ACCUF+48	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	98	0	0-0700	C-ACCUF+49	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	99	0	0-1-00A0	C-ACCUF+49	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	100	0	0-0700	C-ACCUF+50	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	101	0	0-1-00A0	C-ACCUF+50	0-16AUF+07	0-01AUF+07	1-0350	60-130	0-740													
1	1	102	0	0-0700	C-ACCUF+51	0-16AUF+07	0-59AUF+06	1-0350	60-130	0-740													
1	1	103	0	0-1-00A0	C-ACCUF+51	0-16AUF+07	0-59AUF+07	1-0350	60-130	0-740													
1	1	104	0	0-0700	C-ACCUF+52	0-16AUF+07	0-01AUF+06	1-0350	60-130	0-740													
1	1	105	0	0-1-00A0	C-ACCUF+52	0-16AUF+07	0-01AUF+07	1-0350	60-130														

0.00000000 0.00000000 180.00 450.00 160.00 0.2830E+07 1.7400 56.00 0.00100									
TYPE	AM	RTM	AWD	RTM	AW	HT	AT	RTS	HEIGHT
1	10366.00	3.70	4110.00	0.89	2100.00	14.29	2073.00	10.00	27.50
2	4784.00	20.00	310.00	0.89	1714.00	16.67	1874.00	4.91	23.00
3	5250.00	4.00	512.00	0.89	3664.00	4.55	3762.00	4.91	17.50
4	5254.20	3.45	909.00	0.89	2125.00	16.67	2074.00	4.91	28.50
5	7300.00	3.70	2431.00	0.89	6000.00	17.53	6000.00	6.50	90.00
6	7106.30	3.70	1420.00	0.89	1162.00	3.33	1162.00	6.00	15.80
7	10552.00	7.13	3000.00	0.89	20464.00	5.89	20464.00	5.27	15.00
8	14882.00	5.00	5662.00	0.89	9135.00	20.00	8135.00	4.04	23.00
9	14882.00	2.63	5662.00	0.89	18830.00	5.22	18830.00	4.00	20.00
10	25590.00	2.44	5633.00	0.89	17000.00	5.72	17000.00	4.50	30.00
11	20590.00	2.44	5633.00	0.89	17000.00	5.72	17000.00	4.50	30.00

Information Processing Center									
TYPE	AM	RTM	AWD	RTM	AW	HT	AT	RTS	HEIGHT
1	70.00	40.000	0.500	0.00	1.700	0.660	10164.00	0.034	0.700
2	31.00	40.000	0.500	1.95	1.700	0.660	4784.00	0.019	0.800
3	132.00	40.000	0.500	3.96	1.700	0.660	5250.00	0.016	0.700
4	33.00	40.000	0.500	2.96	1.700	0.660	5254.20	0.010	0.700
5	232.00	40.000	0.500	12167	3.200	0.660	7300.00	0.024	0.700
6	176.00	40.000	0.500	272	3.200	0.660	7106.30	0.010	0.600
7	66.00	40.000	0.500	120	3.200	0.660	10552.00	0.004	0.600
8	90.00	40.000	0.500	1304	3.200	0.660	14882.00	0.004	0.600
9	150.00	40.000	0.500	3816	3.200	0.660	14882.00	0.004	0.600
10	86.00	40.000	0.500	2368	3.200	0.660	17000.00	0.004	0.600
11	86.00	40.000	0.500	2368	3.200	0.660	20590.00	0.004	0.600

Information Processing Center									
TYPE	AM	RTM	AWD	RTM	AW	HT	AT	RTS	HEIGHT
1	944.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	5.17
2	702.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	3.17
3	1103.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	6.53
4	971.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	2.08
5	270031.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	337.06
6	30031.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	72.84
7	25624.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	30.73
8	7813.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	72.34
9	13958.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	41.85
10	13397.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	127.40
11	12818.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	127.40

Information Processing Center									
EXCHANGER	BLDG TYPE	UNITS	COMP AC	ABS AC	RES HT	MT PUMP	MT HT	MTZ HT	
1	1	75	0	75	0	0	0	75	
2	2	0	0	0	0	0	0	0	
3	3	0	0	0	0	0	0	0	
4	4	0	0	0	0	0	0	0	
5	5	0	0	0	0	0	0	0	
6	6	0	0	0	0	0	0	0	
7	7	0	0	0	0	0	0	0	
8	8	12	0	12	0	0	0	12	
9	9	2	0	2	0	0	0	2	
10	10	0	0	0	0	0	0	0	
11	11	0	0	0	0	0	0	0	
12	12	0	0	0	0	0	0	0	
13	13	0	0	0	0	0	0	0	
14	14	0	0	0	0	0	0	0	
15	15	0	0	0	0	0	0	0	
16	16	0	0	0	0	0	0	0	
17	17	0	0	0	0	0	0	0	
18	18	0	0	0	0	0	0	0	
19	19	0	0	0	0	0	0	0	
20	20	0	0	0	0	0	0	0	
21	21	0	0	0	0	0	0	0	
22	22	0	0	0	0	0	0	0	

1

[illegible]

COMP AC EFF	ARS AC EFF	RES HT EFF	HT PUMP EFF	H2O HT EFF
2.00	0.75	1.00	2.40	1.00
LATITUDE	SOLAR DECL	APP SOLAR CCNST	ATM EXT COFF	SKY DIFF FAC
35.00	-20.00	390.	0.142	0.058

THERMAL/ELECTRIC CONVERSION EFFICIENCY: 0.3300

PUMP RESPONSE SENSITIVITY FACTOR: 2.0

CASE MASS FLOW INPUT SCALE FACTOR: 1.0000

REACTOR TOTAL THERMAL POWER OUTPUT: 150. MW(TH)

Information Processing Center

Information Processing Center

Information Processing Center

Information Processing Center

WEATHER DATA EIGHTH IDN

TIME	AIR TEMPERATURE (F)	WIND VELOCITY (MPH)	WIND DIRECTION (FROM NORTH)
0100	22.00	15.00	270.00
1100	21.00	15.00	270.00
2100	18.00	15.00	270.00
3100	15.00	15.00	270.00
4100	16.00	15.00	270.00
5100	17.00	15.00	270.00
6100	18.00	15.00	270.00
7100	21.00	15.00	270.00
8100	23.00	15.00	270.00
9100	26.00	15.00	270.00
10100	27.00	15.00	270.00
11100	30.00	15.00	270.00
12100	33.00	15.00	270.00
13100	35.00	15.00	270.00
14100	31.00	15.00	270.00
15100	32.00	15.00	270.00
16100	29.00	15.00	270.00
17100	30.00	15.00	270.00
18100	30.00	15.00	270.00
19100	29.00	15.00	270.00
20100	27.00	15.00	270.00
21100	25.00	15.00	270.00
22100	23.00	15.00	270.00
23100	22.00	15.00	270.00
24100			

Information Processing Center

Information Processing Center

ELECTRICAL LOAD DISTRIBUTION (EXCLUDING HEATING)

TIME	LOAD (KWE)	BASE LOAD FRACTION
0:00	19.6	0.56
1:00	18.9	0.54
2:00	17.8	0.51
3:00	17.5	0.50
4:00	17.8	0.51
5:00	18.2	0.52
6:00	19.3	0.55
7:00	22.0	0.63
8:00	27.3	0.78
9:00	30.4	0.87
10:00	31.5	0.90
11:00	31.5	0.90
12:00	30.8	0.88
13:00	32.4	0.87
14:00	29.8	0.85
15:00	29.4	0.84
16:00	28.7	0.82
17:00	28.7	0.82
18:00	29.4	0.84
19:00	31.5	0.90
20:00	35.0	1.00
21:00	33.9	0.97
22:00	30.1	0.86
23:00	26.3	0.75
24:00	19.6	0.56

Information Processing Center

Information Processing Center

Information Processing Center

Information Processing Center

BUILDING USE FACTORS

TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	0.81	0.81	0.81	0.81	0.53	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
1	0.67	0.67	0.67	0.67	0.41	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
2	0.61	0.61	0.61	0.61	0.41	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
3	0.58	0.58	0.58	0.58	0.41	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
4	0.52	0.52	0.52	0.52	0.41	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
5	0.59	0.49	0.49	0.49	0.38	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
6	0.52	0.52	0.52	0.52	0.53	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
7	0.59	0.59	0.59	0.59	0.60	0.30	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
8	0.66	0.66	0.66	0.66	0.71	0.30	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20
9	0.69	0.69	0.69	0.69	0.69	0.48	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.20
10	0.79	0.79	0.79	0.79	0.79	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.20
11	0.90	0.90	0.90	0.90	0.90	0.98	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	0.20
12	0.93	0.93	0.93	0.93	0.93	0.99	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	0.20
13	0.96	0.96	0.96	0.96	0.96	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	0.20
14	0.96	0.96	0.96	0.96	0.96	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	0.20
15	0.93	0.93	0.93	0.93	0.93	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	0.20
16	0.95	0.95	0.95	0.95	0.95	0.95	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	0.20
17	0.93	0.93	0.93	0.93	0.93	0.93	0.93	1.00	0.93	1.00	0.93	1.00	0.93	1.00	0.93	1.00	0.93	1.00	0.93	0.20
18	0.58	0.98	0.98	0.98	0.98	0.75	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	0.20
19	1.00	1.00	1.00	1.00	1.00	0.70	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	0.20
20	0.59	0.99	0.99	0.99	0.99	0.70	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	1.00	0.10	0.20
21	0.95	0.96	0.96	0.96	0.96	0.96	0.96	1.00	0.96	1.00	0.96	1.00	0.96	1.00	0.96	1.00	0.96	1.00	0.96	0.20
22	0.93	0.93	0.93	0.93	0.93	0.95	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	1.00	0.95	0.20
23	0.87	0.87	0.87	0.87	0.87	0.56	0.10	0.80	0.55	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
24	0.81	0.81	0.81	0.81	0.53	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20

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SERVICE HJT WATER USE FACTORS

TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	0.33	0.17	0.17	0.17	0.53	0.0	0.0	C.C	0.0	0.0	0.33	0.33								
1	0.26	0.14	0.14	0.14	0.41	0.0	0.0	C.C	0.0	0.0	0.26	0.26								
2	0.18	0.13	0.13	0.13	0.41	0.0	0.0	0.0	0.0	0.0	0.18	0.18								
3	0.11	0.10	0.10	0.10	0.41	0.0	0.0	C.C	0.0	0.0	0.11	0.11								
4	0.03	0.11	0.11	0.11	0.41	0.0	0.0	0.0	0.0	0.0	0.03	0.03								
5	0.04	0.10	0.10	0.10	0.38	0.0	0.0	C.C	0.0	0.0	0.04	0.04								
6	0.01	0.10	0.10	0.10	0.53	0.0	0.0	C.C	0.0	0.0	0.01	0.01								
7	0.11	0.13	0.13	0.13	0.60	0.0	0.0	C.C	0.0	0.0	0.11	0.11								
8	0.18	0.15	0.15	0.15	0.71	0.0	0.0	C.C	0.0	0.0	0.18	0.18								
9	0.21	0.25	0.25	0.25	0.88	0.0	0.0	C.C	0.0	0.0	0.21	0.21								
10	0.22	0.21	0.21	0.21	0.94	0.0	0.0	C.C	0.0	0.0	0.22	0.22								
11	0.18	0.19	0.19	0.19	0.98	0.0	0.0	C.C	0.0	0.0	0.18	0.18								
12	0.26	0.17	0.17	0.17	0.95	0.0	0.0	0.0	0.0	0.0	0.26	0.26								
13	0.16	0.18	0.18	0.18	1.00	0.0	0.0	C.C	0.0	0.0	0.16	0.16								
14	0.13	0.15	0.15	0.15	1.00	0.0	0.0	C.C	0.0	0.0	0.13	0.13								
15	0.16	0.13	0.13	0.13	1.00	0.0	0.0	C.C	0.0	0.0	0.16	0.16								
16	0.24	0.12	0.12	0.12	0.95	0.0	0.0	C.C	0.0	0.0	0.24	0.24								
17	0.20	0.12	0.12	0.12	0.93	0.0	0.0	C.C	0.0	0.0	0.20	0.20								
18	0.26	0.15	0.15	0.15	0.75	0.0	0.0	C.C	0.0	0.0	0.26	0.26								
19	0.39	0.19	0.19	0.19	0.73	0.0	0.0	C.C	0.0	0.0	0.39	0.39								
20	0.29	0.21	0.21	0.21	0.70	0.0	0.0	C.C	0.0	0.0	0.29	0.29								
21	0.16	0.18	0.18	0.18	0.68	0.0	0.0	C.C	0.0	0.0	0.16	0.16								
22	0.26	0.15	0.15	0.15	0.59	0.0	0.0	C.C	0.0	0.0	0.26	0.26								
23	0.37	0.13	0.13	0.13	0.56	0.0	0.0	C.C	0.0	0.0	0.37	0.37								
24	0.33	0.17	0.17	0.17	0.53	0.0	0.0	C.C	0.0	0.0	0.33	0.33								

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BUILDING ROOM TEMPERATURES (F)

TIME	1	2	3	4	5	6	7	8	9	10	11	12	1	16	15	16	17	18	19	20
0	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
1	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
2	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
3	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
4	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
5	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
6	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
7	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
8	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
9	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
10	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
11	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
12	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
13	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
14	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
15	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
16	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
17	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
18	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
19	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
20	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
21	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
22	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
23	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									
24	68.	72.	72.	72.	74.	65.	70.	70.	65.	68.	70.									

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A.6.2 Building Energy Demands

Whenever IDES=1 in input, the first system analysis data to be output is a summary of the individual building type space conditioning loads calculated for the specified initial weather and building usage conditions (i.e., the loads at time $t = \text{IBHR}$). These individual unit demands are then aggregated according to the specified distributions of buildings and end-use equipment, and the resulting load distribution is printed by building type for each load center heat exchanger and for those buildings in the "external system" not supplied by the TUS. (It should be noted that the printed loads are the net heat losses/gains for the buildings prior to being scaled by the end-use equipment COPs and that they include domestic hot water demands). For TUS heat exchanger design and system initialization purposes, the total thermal energy demands at each load center heat exchanger (including the effects of the consumer equipment COPs, but not of heat losses in the piping) are printed. If an hourly building analysis is desired, the individual building type space conditioning load summary is printed for every set of hourly data points provided, but no further distribution data is supplied. Shown below are the outputs of the building space heating demands, the building load distribution, and the load center heat exchanger thermal demands corresponding to the initial conditions specified in the sample input data.

TIME	WINDING	CONDUCTION	INFILTRATION	WINDOW SOLAR	LIGHTING	TOTAL LOAD
0	1	0.3559E+06	0.5100E+05	0.0	0.1303E+05	0.3835E+06
0	2	0.4762E+05	0.3071E+05	0.0	0.8761E+04	0.7127E+05
0	3	0.1385E+06	0.7556E+05	0.0	0.4105E+05	0.1960E+06
0	4	0.1347E+06	0.4337E+05	0.0	0.5797E+04	0.1721E+06
0	5	0.2739E+07	0.4037E+07	0.0	0.6095E+06	0.1017E+08
0	6	0.2982E+06	0.8264E+05	0.0	0.7793E+04	0.3750E+06
0	7	0.3590E+06	0.1953E+06	0.0	0.1573E+05	0.5426E+06
0	8	0.5102E+06	0.8474E+05	0.0	0.1234E+05	0.5026E+06
0	9	0.8289E+06	0.1637E+06	0.0	0.2162E+05	0.9712E+06
0	10	0.8845E+06	0.1331E+06	0.0	0.8694E+05	0.9307E+06
0	11	0.8539E+06	0.1329E+06	0.0	0.8694E+05	0.8999E+06

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EXCHANGER

LOAD (BTU/HR)

4	0.4091E+08
5	0.2652E+08
6	0.2378E+08
7	0.1653E+08
8	0.3205E+08
9	0.3561E+08
10	0.4014E+08
11	0.1515E+08
12	0.4480E+08
13	0.4514E+08
14	0.1374E+08
15	0.3422E+08

TERMINATION CODE READ

A.6.3 Steady-State System Analysis

When the steady-state system analysis is executed, the individual building type space conditioning loads are computed and printed as in the building load analysis option described above. The demands are then aggregated, scaled by the equipment COPs, and are applied to the load center heat exchangers. When TUS convergence is achieved, a nodal parameter summary is printed which includes fluid temperatures, fluid mass flowrates, the steady-state nodal energy flows, loop circulation pump pressure settings, fluid conditions on both sides of the TUS supply heat exchanger, and specifications of the heat stored in each section of the thermal reservoir. (It should be remembered that the values printed for the reservoir stored energy are only relative indicators of the actual energy storage trends, and that the water volume data provides the absolute heat storage information). Following this TUS summary, the building load distribution on a per-heat-exchanger basis is printed for the steady-state demand conditions, and overall TUS and power plant energy supply/demand data is summarized. The building loads and the demand distribution data output for this option are identical to those illustrated in Section A.6.2. The converged steady-state TUS nodal summary corresponding to the sample initial conditions is shown below.

TIME = C.O. HR

CONSUMER BRANCH DATA

LCOP	NODE	Y	INLET TEMP (F)	OUTLET TEMP (F)	MASS FLOW (LBM/HR)	HEAT DEMAND (BTU/HR)
1	1	1	80.00	240.00	0.2557E+06	0.4021E+08
1	2	1	80.00	240.00	0.1657E+06	0.2652E+08
1	3	1	80.00	240.00	0.1687E+06	0.2378E+08
2	1	2	80.00	240.00	0.1633E+06	0.1693E+08
2	2	2	80.00	240.00	0.2003E+06	0.3205E+08
2	3	2	80.00	240.00	0.2225E+06	0.3561E+08
2	4	2	80.00	240.00	0.2509E+06	0.4019E+08
3	1	3	80.00	270.00	0.1093E+06	0.1515E+08
3	2	3	80.00	270.00	0.3203E+06	0.4400E+08
3	3	3	80.00	270.00	0.3227E+06	0.4514E+08
3	4	3	80.00	270.00	0.9025E+05	0.1374E+08
3	5	3	80.00	270.00	0.2447E+06	0.3422E+08

SECONDARY LCOP DATA

LCOP	SUPPLY TEMP (F)	RETURN TEMP (F)	MASS FLOW (LBM/HR)	HEAT DEMAND (BTU/HR)	NODE	SUPPLY TEMP (F)	RETURN TEMP (F)	MASS FLOW (LBM/HR)
1	368.45	86.27	0.3277E+06	0.9339E+08	2	364.31	89.38	0.1473E+06
					3	364.31	89.49	0.9554E+05
					6	364.31	89.57	0.9479E+05
2	315.03	84.34	0.5542E+06	0.1265E+09	2	310.59	89.27	0.7430E+05
					3	310.59	86.68	0.1512E+06
					4	310.59	86.58	0.1502E+06
					5	310.59	89.45	0.1606E+06
3	243.15	83.20	0.9731E+06	0.1557E+09	2	241.71	85.07	0.7671E+05
					3	241.71	85.13	0.2261E+06
					4	241.71	85.23	0.2886E+06
					5	241.71	83.91	0.4708E+05
					6	241.71	82.41	0.2148E+06

HTW LCOP DATA

SUPPLY TEMP (F)	RETURN TEMP (F)	TOTAL HEAT DEMAND (BTU/HR)	MASS FLOW (LBM/HR)
380.00	150.83	0.4054E+09	0.1658E+07

RESERVOIR DATA

HOT WATER STORAGE

WATER TEMPERATURE (F)	STORAGE VOLUME (CU.FT.)	STORED HEAT (BTU)
380.00	0.9000E+06	0.1988E+11

COLD WATER STORAGE

WATER TEMPERATURE (F)	STORAGE VOLUME (CU.FT.)	STORED HEAT (BTU)
150.83	0.9000E+06	0.9308E+10

PRECOOLER GAS-SIDE DATA

HELIUM INLET TEMPERATURE (F) 450.00 HELIUM OUTLET TEMPERATURE (F) 160.00 HELIUM MASS FLOW (LBM/HR) 0.1052E+07 HEAT FLOW (BTU/HR) 0.3899E+09

***PRECOOLER WATER-SIDE DATA**

INLET TEMPERATURE (F) 150.83 OUTLET TEMPERATURE (F) 380.00 MASS FLOW (LBM/HR) 0.1609E+07

***PUMP DATA**

PUMP	PRESSURE (PSI)
1	0.7324E+02
2	0.6387E+01
3	0.3625E+02
4	0.7804E+02

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A.6.4 Dynamic System Analysis

When the dynamic system analysis is initialized internally from the converged steady-state TUS parameters, the first block of analysis output data corresponds to the printouts summarized in Sections A.6.2 and A.6.3 for the building load analysis and steady-state TUS analysis program execution options. (In this case, the hourly building load summary and its associated input data are printed following the steady-state system output, since the hourly data is not read into the program until the TUS parameters have converged.)

The output from the dynamic system simulation is scheduled by the user and can be supplied as frequently as every time step or as infrequently as once each hour. Printed output includes the instantaneous TUS nodal summary at the end of the given time step, the instantaneous distribution of building loads at each load center heat exchanger, and a summary of the thermal energy supply/demand mismatches at each heat exchanger in the system. The nodal summary and building load distribution are identical in form to the output illustrated for the steady-state analysis; a sample heat exchanger energy balance output listing is shown below.

EXCHANGER HEAT BALANCE

EXCHANGER	SUPPLY (BTU/HR)	DEMAND (BTU/HR)	DIFFERENCE
1	0.9311E+08	0.9330E+08	0.1546E+05
2	0.1285E+09	0.1284E+09	0.2056E+05
3	0.1557E+09	0.1557E+09	-0.1808E+05
4	0.4117E+08	0.4111E+08	0.6571E+05
5	0.2673E+08	0.2666E+08	0.4176E+05
6	0.2301E+08	0.2294E+08	0.6909E+05
7	0.1679E+08	0.1678E+08	0.1166E+05
8	0.3173E+08	0.3164E+08	0.9217E+05
9	0.3526E+08	0.3523E+08	0.3373E+05
10	0.4034E+08	0.4033E+08	0.1614E+05
11	0.1519E+08	0.1527E+08	-0.2533E+05
12	0.4488E+08	0.4496E+08	-0.7862E+05
13	0.4506E+08	0.4516E+08	-0.9027E+05
14	0.1349E+08	0.1352E+08	-0.2941E+05
15	0.3484E+08	0.3476E+08	0.8085E+05

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Also output from the dynamic simulation is a punched card deck containing specifications of the instantaneous TUS total thermal load (including all losses), the instantaneous TES total electrical demand, and the volume of water contained in the hot section of the thermal energy storage reservoir at the end of each output interval time step. These overall system parameters are output in a format easily adapted to integrated energy consumption analyses (see, for example, Reference 14) or to simple hourly system summary data plotting routines. The composition and format of this data deck is:

1. Header card:

c.c. 1-7	F7.2	power plant electrical rating in MWe
c.c. 8-12	F5.2	power plant thermal/elec- trical energy conversion efficiency (decimal fraction)

2. System data cards (one punched for initial conditions and at each specified output interval during dynamic analysis)

c.c. 1-8	F8.2	total TUS thermal load in MWt
c.c. 12-19	F8.2	total TES electrical load in MWe

213.

c.c. 23-30

F8.2

water volume in reservoir

hot water section in

10^4 ft³*

*For most moderately-sized systems, this unit of storage produces punched values for the water volume of magnitudes comparable to those for the thermal and electrical energy demands and, therefore, easily adapted to a single set of plotting axes.

A.7 TDIST Variable Definitions

TDIST Variable Definitions

<u>Variable</u>	<u>Definition</u>
A(J)	Coefficient in window solar heat gain formula for absorption of incident radiation
AC	Nodal cross-sectional flow channel area (ft ²)
ACC(NP)	Fluid acceleration through pump NP during one time step (lbm/hr ²)
AEC	Atmospheric extinction coefficient (dimensionless)
AF(I)	Area of Building Type I in contact with the earth (ft ²)
AINFL(I)	Maximum rate of forced-air ventilation for Building Type I (CFM)
ALAT	Latitude of site (degrees)
ALEAK	Total air exchanger between interior and exterior of building (CFH or CFM)
ALPL	Heat exchanger fluid temperature decay constant (dimensionless)
AMAS(K,L,N)	Desired nodal fluid mass flowrate (lbm/hr)
AMS(L)	Desired fluid mass flowrate in secondary loop L (lbm/hr)
AR(I)	Roof area of Building Type I (ft ²)
ASC	Apparent solar constant (BTU/hr-ft ²)
ATD(K,L,N)	Linear average difference between nodal fluid temperature and that of surroundings (°F)

ATDP	Linear average temperature difference across heat exchanger ($^{\circ}\text{F}$)
ATI(ID,JD,KD)	Dummy nodal fluid inlet temperature ($^{\circ}\text{F}$)
ATO(ID,JD,KD)	Dummy nodal fluid outlet temperature ($^{\circ}\text{F}$)
AUF(K,L,N)	Nodal heat transfer coefficient ($\text{BTU/hr-}^{\circ}\text{F}$)
AUG	Building ground-contact material conduction heat transfer coefficient ($\text{BTU/hr-}^{\circ}\text{F}$)
AUR	Roof Conduction Heat Transfer Coefficient ($\text{BTU/hr-}^{\circ}\text{F}$)
AUW	Total wall and window conduction heat transfer coefficient ($\text{BTU/hr-}^{\circ}\text{F}$)
AW(I)	Total exposed wall area of Building Type I (ft^2)
AWD(I)	Total window area of Building Type I (ft^2)
B	Heat exchanger heat transfer coefficient ($\text{BTU/hr-}^{\circ}\text{F}$)
BABS	Temperature-adjusted absorptive air conditioner coefficient of performance
BADC	Cooling equipment coefficient of performance adjustment factor
BADH	Heating equipment coefficient of performance adjustment factor
BCMP	Temperature-adjusted compressive air conditioner coefficient of performance
BH(I)	Height of Building Type I (ft)

BHPM	Temperature-adjusted heat pump coefficient of performance
BMAS(1,1,N)	Desired fluid mass flowrate in bypass around primary loop heat exchanger node N (lbm/hr)
BPDIS	Inverse sum of parallel node pressure drop factors ($\text{ft}^5/\text{hr-lbf}$)
BUF(I,NN)	Use factor of Building Type NN at hour I of simulation (decimal fraction) 0 = Building unoccupied, no equipment use 1 = Full occupancy, all lights, appliances ventilation in use
BUF(25,I)	Use factor of Building Type I at beginning of simulation (decimal fraction) 0 = Building unoccupied, no equipment use 1 = Full occupancy, all lights, appliances ventilation in use
CAP(K,L,N)	Nodal fluid specific heat (BTU/lbm-°F)
CAPG	Specific heat of power plant coolant in pre-cooler (BTU/lbm-°F)
CITY	Alphanumeric run title
COND(K,L,N)	Nodal heat conduction rate (BTU/hr)
CONV(K,L,N)	Nodal heat convection rate (BTU/hr)
CS	Solar incidence direction cosine
CSFAC	Case input mass flowrate scale factor (1.0)

CTH(I)	Cosine of incident solar radiation relative to normal to surface I I = 1-4 = walls, clockwise from north I = 5 = roof
CVO	Volume of cold water section of reservoir (ft ³)
CVOI	Volume of cold water section of reservoir (ft ³)
CW	Solar incidence direction cosine
CZ	Solar incidence direction cosine
DCL(I)	Total length of cracks around all exterior doors in Building Type I (ft)
DECL	Solar declination (degrees)
DENOM	Heat exchanger heat balance coefficient (dimensionless)
DFSI(NN)	Diffuse solar radiation intensity incident on wall NN (BTU/hr-ft ²)
DFSIR	Diffuse solar radiation intensity incident on roof (BTU/hr-ft ²)
DHW(I)	Maximum energy demand for domestic hot water use in Building Type I (BTU/hr)
DIA(K,L,N)	Nodal flow channel diameter (ft)
DINC(I)	Infiltration air flow coefficient C for doors in Building Type I (CFM/ft-in. H ₂ O)
DINN(I)	Infiltration air flow coefficient N for doors in Building Type I (dimensionless)

DL	Distance fluid flows during one time step (ft)
DLK	Total air infiltration through cracks around doors (CFM)
DM	Loop fluid mass flowrate at end of time step (lbm/hr) (FLOWS)
DM	Nodal fluid mass flowrate (lbm/hr) (PRESS)
DMAS(1,1,N)	Desired fluid mass flowrate in primary loop heat exchanger node N (lbm/hr)
DNSI	Direct normal solar intensity (BTU/hr-ft ²)
DP	Nodal fluid frictional pressure loss (lbf/ft ²)
DPM(L)	Maximum free-flow parallel node pressure loss for loop L (lbf/ft ²)
DQ(NE)	Thermal demand at heat exchanger NE (BTU/hr)
DSI(NN)	Direct solar radiation intensity incident on wall NN (BTU/hr-ft ²)
DSIR	Direct solar radiation intensity incident on roof (BTU/hr-ft ²)
DTC	Nodal outlet increment fluid temperature loss due to heat conduction to the surroundings (°F)
DTIME	Size of one time step (decimal fraction of an hour)
DTLM	Nodal log-mean temperature difference (°F)
DTLMX	Log-mean temperature difference over heat exchanger outlet fluid flow increment length (°F)

EABS	Nominal coefficient of performance of absorp- tive air conditioners
ECMP	Nominal coefficient of performance of compres- sive air conditioners
EFF	Power plant thermal/electrical conversion efficiency (%)
EHPM	Nominal coefficient of performance of heat pumps
EHWS	Nominal efficiency of hot water heating
ELBL	Peak non-space-conditioning electrical demand (MWe)
ELF(I)	Non-space-conditioning electric load factor at hour I of simulation (decimal fraction of peak load)
ELF(25)	Non-space-conditioning electric load factor at beginning of simulation (decimal fraction of peak load)
ERES	Nominal efficiency of resistance heaters
ESCL	Total system electric space conditioning load (BTU/hr)
ETHL(IHR)	Total system electric space conditioning load at simulation hour IHR (BTU/hr)
F	Moody-Weisbach friction factor (dimensionless)
FAC1-FAC4	Coefficients in expansion for window solar heat gain formula

FCTR	Conversion factor ($\text{lbm-ft}^2/\text{lbf-hr}^2$)
FF(IX)	Friction factor for heat exchanger IX exclusive of valve resistance (dimensionless)
FHPEX(I)	Fraction of units of Building Type I not served by the Thermal Utility System which are supplied by heat pumps
FP	Nodal fluid friction factor including valve resistance (dimensionless)
FRCN	Incremental/total heat exchanger heat flow ratio (dimensionless)
FREXT(I)	Fraction of units of Building Type I not served by the Thermal Utility System which are supplied by resistance heaters
FV(IX)	Valve friction factor for heat exchanger IX (dimensionless)
FWLIT(I,NN)	Fraction of surface NN lit by direct sunlight for Building Type I (decimal fraction) NN: 1-4 = walls, with 1 defined by normal direction WA, numbered clockwise from north 5 = roof
G	Conversion factor ($\text{lbm-ft}/\text{lbf-hr}^2$)
H	Angular position of solar disk relative to noon normal (radians from normal)

HRF	Elapsed fraction of hourly interval being examined
HVO	Volume of hot water section of reservoir (ft ³)
HVOI	Volume of hot water section of reservoir (ft ³)
IBEG	Beginning hour of simulation period
IBHR	Beginning hour of the simulation period (0-23) 0 = midnight 12 = noon
IDES	Design option code 0 = perform standard utility system analysis 1 = perform building load analysis only
IEND	Endpoint of simulation period
IERR	Data error code 0 = no error 1 = error
IEX(K,L,N)	Nodal heat exchanger code 0 = no heat exchanger 1-30 = heat exchanger
IFLO	Fluid flow calculation code 0 = pump reset or initialization 1 = normal time step sequence
IHR	End point of hourly interval being examined
IHRL	Beginning of hourly interval being examined
IIN	Computer system card reader input device number

INIT	Pump pressure initialization code
	0 = compute loop pressure losses
	1 = reset flow valves and pump settings
IOUT	Computer system line printer output device number
IPMP(K,L,N)	Nodal pump code
	0 = no pump
	1 = pump
IPNCH	Computer system card punch output device number
IPRE	Unused variable
IPRM	Unused variable
IPRX	Unused variable
ISER(K,L,N)	Nodal series/parallel flow code
	0 = series
	1 = parallel
ITIM	Hour of simulation being studied
JPM	Thermostat limit indicator
	0 = limits not exceeded
	1 = limits exceeded, pump reset to take place
K1(NEX)	Heat exchanger NEX supply-side group index
K2(NEX)	Heat exchanger NEX demand-side group index
KODE	Simulation control code
	0 = steady-state analysis
	1 = transient analysis
	2 = end of simulation

KODP	Consumer summary print code
	0 = no print
	1 = print
L1(NEX)	Heat exchanger NEX supply-side loop index
L2(NEX)	Heat exchanger NEX demand-side loop index
LONG(K,L,N)	Nodal flow channel length (ft)
LS	Number of secondary distribution loops
M	Primary loop node indicator
MASS(K,L,N)	Nodal fluid mass flowrate (lbm/hr)
MGAS	Power plant coolant mass flowrate through precooler (lbm/hr)
MTR(I)	Roof surface material type for Building Type I (surface roughness classes identical to those for MTW(I))
MTW(I)	Wall exterior surface material type for Building Type I
	1 = stucco 3 = concrete 5 = plaster
	2 = brick 4 = pine 6 = glass
MU(K,L,N)	Nodal fluid viscosity (lbm/hr-ft)
N1(NEX)	Heat exchanger NEX supply-side node index
N2(NEX)	Heat exchanger NEX demand-side node index
NA	Nodal indicator number
NABS(IX,I)	Number of units of Building Type I served by heat exchanger IX which have absorptive air conditioning

NB(L)	Number of consumer load heat exchangers served by loop L
NBOI	Dummy variable for number of consumer heat exchangers served by a secondary loop
NCMP(IX,I)	Number of units of Building Type I served by heat exchanger IX which have compressive air conditioning
ND(L)	Number of nodes in secondary loop L
NDOI	Dummy variable for number of nodes in a secondary loop
NDUM	Load center heat exchanger supply node indicator
NEX	Heat exchanger number
NEXCH	Total number of heat exchangers in utility system
NH	Number of nodes in primary HTW loop
NHPM(IX,I)	Number of units of Building Type I served by heat exchanger IX which have heat pumps
NHR	Endpoint of hourly interval being examined
NIWS(IX,I)	Number of units of Building Type I served by heat exchanger IX which have hot water heat
NITR	Number of print intervals per hour
NMK	Load center heat exchanger supply node indicator
NNODE	Dummy variable, unused
NP	Secondary loop node indicator

NPMP	Number of pumps in utility system
NPRNT	Number of time steps between print intervals
NRES(IX,I)	Number of units of Building Type I served by heat exchanger IX which have resistance heaters
NSTEP	Number of time steps per hour
NTB(NEX)	Number of tubes in heat exchanger NEX
NTEMP	Number of hours in simulation period
NTYPE	Number of building types in community
NU(IX,I)	Number of units of Building Type I served by heat exchanger IX
NUEX(I)	Number of units of Building Type I <u>not</u> served by the Thermal Utility System
PC	Stack-effect pressure on building (in. H ₂ O)
PC(I)	Percent change in fluid mass flowrate through pump I during one time step
PCI	Percent increase in loop fluid mass flowrate during one time step
PEX(I)	Compensated pressure setting for pump I (lbf/ft ²)
PMF	Precooler fluid mass flowrate (lbm/hr)
PMFI	Precooler fluid mass flowrate (lbm/hr)
POL(I)	Maximum rate of heat generation due to lighting, appliances, people, etc. for Building Type I (KW)
PP(I)	Total fluid frictional pressure head faced by pump I (lbf/ft ²)

PREF(I)	Reference pressure setting for pump I (lbf/ft ²)
PS(I)	Pressure setting for pump I (lbf/ft ²)
PSENS	Pump response sensitivity factor
PT	Total pressure drop across wall (in. H ₂ O)
PTKN	Normal air flow pressure drop coefficient (dimensionless)
PTKO	Oblique air flow pressure drop coefficient (dimensionless)
PV	Normal wind-induced pressure loading on wall (in. H ₂ O)
PW	Wind-induced pressure loading on wall (in. H ₂ O)
Q	Total heat loss from buildings of one type served by a given load center heat exchanger (BTU/hr)
QABS	Energy demand from absorptive air conditioners (BTU/hr)
QAEXT	Energy demand from absorptive air conditioners in buildings not served by Thermal Utility System (BTU/hr)
QCEXT	Energy demand from compressive air conditioners in buildings not served by Thermal Utility System (BTU/hr)
QCI	Heat stored in reservoir cold water section (BTU referenced to 0 °F)
QCMP	Energy demand from compressive air conditioners (BTU/hr)

QCO	Heat stored in reservoir cold water section (BTU referenced to 0 °F)
QCOND(I)	Total heat loss due to conduction from Building Type I (BTU/hr)
QCW	Heat stored in reservoir cold water section (BTU referenced to 0 °F)
QD	Thermal demand at heat exchanger (BTU/hr)
QDEXT	Total domestic hot water energy demand for buildings of a given type not served by Thermal Utility System (BTU/hr)
QDHW	Total domestic hot water energy demand for build- ings of one type served by a given load center heat exchanger (BTU/hr)
QDIF	Supply/demand imbalance at heat exchanger (BTU/hr)
QDO(NX)	Thermal demand at heat exchanger NX (BTU/hr)
QEXT	Total heat loss from all buildings of a given type not served by Thermal Utility System (BTU/hr)
QHEXT	Energy demand from heat pumps in buildings not served by Thermal Utility System (BTU/hr)
QHI	Heat stored in reservoir hot water section (BTU referenced to 0 °F)
QHO	Heat stored in reservoir hot water section (BTU referenced to 0 °F)
QHPM	Energy demand from heat pumps (BTU/hr)

QHS	Thermal energy available to thermal utility system after electrical generation (BTU/hr)
QHW	Heat stored in reservoir hot water section (BTU referenced to 0 °F)
QHWEX	Energy demand from hot water heating in buildings not served by Thermal Utility System (BTU/hr)
QHWS	Energy demand from hot water heat (BTU/hr)
QL(IHR,I)	Total heat loss from Building Type I at simulation hour IHR (BTU/hr)
QLEAK(I)	Heat loss rate from Building Type I due to infiltration/ventilation (BTU/hr)
QLIG(I)	Internal heat generation rate for Building Type I due to non-space conditioning equipment and people (BTU/hr)
QRES	Energy demand from resistance heaters (BTU/hr)
QREXT	Energy demand from resistance heaters in buildings not served by Thermal Utility System (BTU/hr)
QS	Thermal supply at heat exchanger (BTU/hr)
QS(L)	Total thermal demand at load center heat exchangers in loop L (BTU/hr)
QTL D	Total thermal demand at load center heat exchangers (BTU/hr)
QTL D	Total thermal demand at load center heat exchangers (BTU/hr)

QWDSG(I)	Heat gain through windows for Building Type I (BTU/hr)
RE	Fluid Reynold's number (dimensionless)
REFF	Required power plant generation efficiency to meet total system electrical demand at specified thermal power rating
REFM	Reference primary loop fluid mass flowrate (lbm/hr)
REFT	Reference primary loop return temperature ($^{\circ}\text{F}$)
RHO	Roof surface convective film heat transfer coefficient ($\text{BTU/hr-ft}^2\text{-}^{\circ}\text{F}$)
RHO(K,L,N)	Nodal fluid density (lbm/ft^3)
RMAS	Desired fluid mass flowrate in primary loop (lbm/hr)
RPE(L)	Parallel node fluid flow resistance for loop L (lbf-hr/ft^5)
RRSIZ	Power plant rating to meet total system electrical demand at specified generation efficiency (MWt)
RS	Power plant electrical generation capacity (MWe)
RSAB(I)	Roof material solar absorptivity for Building Type I
RTBL	Power plant base - load thermal output (MWt)
RTF(I)	Building Type I ground-contact material thermal resistance ($\text{hr-ft}^2\text{-}^{\circ}\text{F/BTU}$)

RTHRM	Power plant base-load thermal output (BTU/hr)
RTR(I)	Roof thermal resistance of Building Type I (hr-ft ² -°F/BTU)
RTW(I)	Wall thermal resistance of Building Type I (hr-ft ² -°F/BTU)
RTWD(I)	Window thermal resistance of Building Type I (hr-ft ² -°F/BTU)
SDF	Sky diffusion factor (dimensionless)
SHGF	Window solar heat gain factor (BTU/hr-ft ²)
STLD	Total thermal utility system load including transmission losses (MWt)
STOR	Reservoir hot water section volume (ft ³ x10 ⁴)
SUMM	Sum of load center heat exchanger fluid mass flowrates (lbm/hr)
SUMT	Sum of mass-flow-weighted load center heat exchan- ger outlet temperatures (lbm-°F/hr)
SWA	Building orientation relative to south (radians)
T(J)	Coefficient in window solar heat gain formula for transmission of incident radiation
TAIR(I)	Ambient air temperature at hour I of simulation (°F)
TAIR(25)	Ambient air temperature at beginning of simula- tion (°F)
TAMB	Ambient earth temperature (°F)

TCG	Power plant coolant temperature at outlet of precooler (°F)
TCW	Reservoir cold water section temperature (°F)
TCWI	Reservoir cold water section temperature (°F)
TD	Nodal outlet temperature difference (°F)
TDX	Temperature difference across nodal boundary one incremental flow length from outlet (°F)
TELD	Total electrical demand from consumer's space conditioning and domestic hot water equipment (BTU/hr, or MWe)
TELLD	Total system electrical load (MWe)
TEO	Secondary loop fluid reference temperature (°F)
THG	Power plant coolant temperature at inlet to pre-cooler (°F)
THI	Reservoir hot water section temperature (°F)
THS	Primary loop fluid reference temperature (°F)
THW	HTW temperature setting at inlet to primary loop (°F)
THWI	Reservoir hot water section temperature (°F)
TI(K,L,N)	Nodal fluid inlet temperature (°F)
TIAB	Absolute temperature to be maintained in building (°K)
TIB(NN)	Temperature to be maintained in Building Type NN (°F)

TIBM	Minimum of temperatures to be maintained in all building types (°F)
TIME	Elapsed time from beginning of simulation (hr)
TIP	Load center heat exchanger fluid inlet temperature at end of time step (°F)
TITLE	Alphanumeric run title
TLD	Total community space conditioning and domestic hot water energy demand (BTU/hr, or MWt)
TLH(IX)	Lower temperature limit setting for supply water to consumers served by heat exchanger IX (°F)
TLP(IX)	Lower temperature limit setting for water at outlet of primary/secondary heat exchanger IX (°F)
TM	Heat exchanger temperature difference ratio
TMAS	Total mass of fluid contained in a node (lbm)
TN	Nodal inlet temperature difference (°F)
TO(K,L,N)	Nodal fluid outlet temperature (°F)
TOAB	Absolute ambient air temperature (°K)
TOB	Ambient air temperature (°F)
TODP	Fluid temperature at one incremental flow length from nodal outlet (°F)
TOP(K,L,N)	Nodal fluid outlet temperature at end of time step (°F)
TPD	Total pressure loss around loop (lbf/ft ²)
TQ(IX)	Thermal demand at load center heat exchanger IX (BTU/hr)

TQL(IHR,IX)	Thermal demand at load center heat exchanger IX at simulation hour IHR (BTU/hr)
TR(L)	Mass-flowrate-averaged fluid temperature at load center heat exchanger return header for loop L (°F)
TRP(IX)	Design temperature setting of water at outlet of primary/secondary heat exchanger IX (°F)
TSAR	Sol-air temperature at roof surface (°F)
TSAW	Sol-air temperature at exterior wall surface (°F)
TSB(I,NN)	Temperature to be maintained in building type NN at hour I of simulation (°F)
TSB(25,I)	Temperature to be maintained in Building Type I at beginning of simulation (°F)
TSET	Heat exchanger steady-state reference tempera- ture (°F)
TTLD	Total thermal demand at a load center heat exchanger (BTU/hr)
TUH(IX)	Upper temperature limit setting for supply water to consumers served by heat exchanger IX (°F)
TUL(IX)	Upper temperature limit setting for return water from consumers served by heat exchanger IX (°F)

TUP(IX)	Upper temperature limit setting for water at outlet of primary/secondary heat exchanger IX ($^{\circ}\text{F}$)
VLEAK	Total air exchange between interior and exterior of building due to ventilation (CFH)
WA(I)	Orientation of Building Type I with respect to North ($0^{\circ} \leq \text{WA} < 90^{\circ}$)
WDCL(I)	Total length of cracks around all windows in Building Type I (ft)
WDINC(I)	Infiltration air flow coefficient C for windows in Building Type I (CFM/ft-in. H_2O)
WDINN(I)	Infiltration air flow coefficient N for windows in Building Type I (dimensionless)
WDIR(I)	Wind direction at hour I of simulation (degrees clockwise from north)
WDIR(25)	Wind direction at beginning of simulation (degrees clockwise from north)
WDLK	Total air infiltration through cracks around windows (CFM)
WDSC(I)	Window interior shading coefficient for Building Type I (decimal fraction; 0=no solar transmission, 1=no shading)
WHO	Exterior wall convective film heat transfer coefficient ($\text{BTU/hr-ft}^2\text{-}^{\circ}\text{F}$)

WHTCA(MTR(I))	} Surface roughness coefficients for Building Type I roof surface material
WHTCB(MTR(I))	
WHTCC(MTR(I))	
WHTCA(MTW(I))	} Surface roughness coefficients for Building Type I exterior wall material
WHTCB(MTW(I))	
WHTCC(MTW(I))	
WINC(I)	Infiltration air flow coefficient C for walls in Building Type I ($\text{CFM}/\text{ft}^2\text{-in. H}_2\text{O}$)
WINN(I)	Infiltration air flow coefficient N for walls in Building Type I (dimensionless)
WLK	Total air infiltration through cracks in walls (CFM)
WSAB(I)	Wall material solar absorptivity for Building Type I
WSGF	Aggregate window solar heat gain factor ($\text{BTU}/\text{hr-ft}^2$)
WUF(I,NN)	Use factor for domestic hot water in building type NN at hour I of simulation (decimal fraction) 0 = no hot water use 1 = use at peak demand rate
WUF(25,I)	Use factor for domestic hot water in Building Type I at beginning of simulation (decimal fraction) 0 = no hot water use 1 = use at peak demand rate

WV(I)	Wind velocity at hour I of simulation (mph)
WV(25)	Wind velocity at beginning of simulation (mph)
X	Heat exchanger energy supply scale factor (hr-°F/BTU)
X(I)	Relative direction of wind relative to normal to wall I (radians)
XRAT	Ratio of fluid mass flowrate through primary heat exchanger to primary loop mass flowrate
Y	Diffuse solar radiation incidence coefficient

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A.8 TDIST Program Listing


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REAL LONG, MASS, MU, MGAS
DOUBLE PRECISION T, TIME
DIMENSION ISER(3,5,13), IEX(3,5,13), IPMP(3,5,13), DIA(3,5,13)
DIMENSION LONG(3,5,13), AUF(3,5,13), MASS(3,5,13), TI(3,5,13)
DIMENSION TO(3,5,13), CAP(3,5,13), RHO(3,5,13), MU(3,5,13), ND(5)
DIMENSION NB(5), K1(31), K2(31), L1(31), L2(31), N1(31), N2(31)
DIMENSION QDO(31), COND(3,5,13), CONV(3,5,13), NTB(31), RPE(5)
DIMENSION AW(20), RTW(20), AWD(20), RTWD(20), AR(20), RTR(20), AF(20)
DIMENSION RTF(20), MTW(20), MTR(20), BH(20), WA(20), AINFL(20)
DIMENSION WDSC(20), FWLIT(20,5), WSAB(20), RSAB(20), POL(20), NUEX(20)
DIMENSION FREXT(20), FHPEX(20), TITLE(20), CITY(20), NU(31,20), TIB(20)
DIMENSION PS(6), PREF(6), PEX(6), PP(6), PC(6), DPM(5), TAIR(25), ELF(25)
DIMENSION WV(25), WDIR(25), TSB(25,20), BUF(25,20), TQL(25,31), TQ(31)
DIMENSION TUL(31), QL(25,20), ETHL(25), DHW(20), WUF(25,20)
DIMENSION AMAS(3,5,13), AMS(5), TLH(31), TUH(31), NABS(31,20)
DIMENSION NCMP(31,20), NRES(31,20), NHPM(31,20), NHWS(31,20)
DIMENSION BMAS(3,5,13), DMAS(3,5,13)
DIMENSION DCL(20), DINC(20), DINN(20), WDCL(20), WDINC(20), WDINN(20)
DIMENSION WINC(20), WINN(20)
DIMENSION TRP(10), TUP(10), TLP(10)
COMMON LS, ND, NH, IOUT, IEX, ISER, NB, CAP, NEXCH, MASS, TI, TO, AUF, K1, K2
COMMON L1, L2, N1, N2, RHO, DIA, LONG, NTR, THW, IERR, TAMB, DTIME, COND, CONV
COMMON KODP, KODE, INIT, IFLO, NTYPE, NU, NPMP, IPMP, MU, TQ, TOB, TIB
COMMON DPM, PP, RPE, PS, PREF, PEX, PC, TCW, HVO, CVO, QHW, QCW, THG
COMMON TCG, MGAS, CAPG, PMF, THI, QHS, QHO, QCO, QDO, PSENS, AMAS
COMMON /ABC/TIME, T
COMMON /XYZ/PMAS, DMAS
COMMON /BLD/AW, PTW, AWD, RTWD, AR, RTR, AF, RTF, MTW, MTR, BH, AINFL
COMMON /BLD/WSAB, RSAB, POL, WV, WDIR, IBHR, ALAT, DECL
COMMON /BLD/ASC, AEC, SDF, BUF, WA, WDSC, FWLIT
COMMON /BLD/ETHL, TOL, NCMP, NABS, NRES, NHPM, NHWS, ECMP, EABS, ERES, EHPM
COMMON /DLE/EHWS, NUEX, FREXT, FHPEX, DHW, WUF
COMMON /AID/QL, NTEMP, TAIR, TSB
COMMON /INFP/DCL, DINC, DINN, WDCL, WDINC, WDINN, WINC, WINN
IIN = 5
IOUT = 6

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IPNCH = 7
TEER = 0
KOP = 1
DO 9999 K=1,3
DO 9998 L=1,5
DO 9997 N=1,13
MASS(K,L,N) = 0.0
AUF(K,L,N) = 0.0
9997 CONTINUE
9998 CONTINUE
9999 CONTINUE
      READ (IIN,8300) TITLE
      READ (IIN,8300) CITY
8300 FORMAT (20A4)
      WRITE (IOUT,8400)
8400 FORMAT (1H1,22X,' *** TDIST - METROPOLITAN THERMAL ENERGY DISTRIBU
TION SYSTEM SIMULATION ***')
      WRITE (IOUT,8401) TITLE
      WRITE (IOUT,8401) CITY
8401 FORMAT (1H0,20X,20A4)
      READ (IIN,1000) NH
1000 FORMAT (I3)
      NNODE = NH
      DO 1 I=1,NH
      READ (IIN,1001) N,ISER(1,1,N),IEX(1,1,N),IPMP(1,1,N),DIA(1,1,N),
1 LONG(1,1,N),AUF(1,1,N)
1001 FORMAT (4I3,F7.4,2E11.4)
      READ (IIN,1002) MASS(1,1,N),TI(1,1,N),TO(1,1,N),CAP(1,1,N),
1 RHO(1,1,N),MU(1,1,N)
1002 FOFMAT (E11.4,2F7.2,3F7.4)
1 CONTINUE
      READ (IIN,1000) LS
      DO 4 L=1,LS
      READ (IIN,1003) ND(L),NB(L)
1003 FORMAT (2I3)
      NNODE = NNODE + ND(L) + NB(L)

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NDOI = ND(L)
DO 2 I=1,NDOI
  READ (IIN,1001) N,ISER(2,L,N),IEX(2,L,N),IPMP(2,L,N),DIA(2,L,N),
  1 LONG(2,L,N),AUF(2,L,N)
  READ (IIN,1002) MASS(2,L,N),TI(2,L,N),TO(2,L,N),CAP(2,L,N),
  1 RHO(2,L,N),MU(2,L,N)
  2 CONTINUE
  NBOI = NB(L)
  DO 3 I=1,NBOI
    READ (IIN,1001) N,ISER(3,L,N),IEX(3,L,N),IPMP(3,L,N),DIA(3,L,N),
    1 LONG(3,L,N),AUF(3,L,N)
    READ (IIN,1002) MASS(3,L,N),TI(3,L,N),TO(3,L,N),CAP(3,L,N),
    1 RHC(3,L,N),MU(3,L,N)
    3 CONTINUE
  4 CONTINUE
  READ (IIN,1000) NEXCH
  DO 5 I=1,NEXCH
    READ(IIN,1004) NEX,K1(NEX),L1(NEX),N1(NEX),K2(NEX),L2(NEX),
    1 N2(NEX),NTB(NEX)
    1004 FORMAT (I3,5X,3I3,5X,3I3,5X,I5)
    5 CONTINUE
    READ (IIN,1000) NPMP
    READ (IIN,1006) HVO,CVO,THW
    1006 FORMAT (2E11.4,F7.2)
    READ (IIN,1005) THG,TCG,MGAS,CAPG
    1005 FORMAT (2F7.2,E11.4,F7.4)
    READ (IIN,1012) TAMB
    READ (IIN,1012) EFF
    READ (IIN,1012) PSENS
    READ (IIN,1007) NSTEP,NPRNT,DTIME
    1007 FORMAT (2I5,F8.5)
    READ (IIN,1000) NTYPE
    DO 6 II=1,NTYPE
      READ (IIN,1008) I,AW(I),RTW(I),AWD(I),RTWD(I),AR(I),RTR(I),AF(I),
      1 RIF(I)
      1008 FORMAT (I2,4(F8.2,F8.3))

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      READ (IIN,10080) I,DCL(I),DINC(I),DINN(I),WDCL(I),WDINC(I),
1    WDINN(I),WINC(I),WINN(I)
10080 FORMAT (I2,8F8.3)
      READ (IIN,10081) I,MTW(I),MTR(I),BH(I),AINPL(I)
10081 FORMAT (I2,2X,I2,2X,I2,2X,F7.2,F10.2)
      READ (IIN,10082) I,WA(I),WDSC(I), (FWLIT(I,NN),NN=1,5),WSAB(I),
1    RSAB(I),POL(I),DHW(I)
10082 FORMAT (I2,F7.2,F5.2,5F5.2,F5.2,F5.2,F9.2,E11.4)
      WA(I) = WA(I)*3.1416/180.
      READ (IIN,10083) I,NUEX(I),FREXT(I),FHPEX(I)
10083 FORMAT (I2,I5,2F5.2)
6    CONTINUE
      DO 8 L=1,LS
      NBOI = NR(L)
      DO 7 N=1,NBOI
      IX = IEX(3,L,N)
      DO 6001 I=1,NTYPE
      READ (IIN,1010) NU(IX,I),NCMP(IX,I),NABS(IX,I),NRES(IX,I),
1    NHPM(IX,I),NHWS(IX,I)
1010 FORMAT (6I5)
6001 CONTINUE
7    CONTINUE
8    CONTINUE
      READ (IIN,1015) ECMP,EABS,ERES,EHPM,EHWS
1015 FORMAT (5F5.2)
      READ (IIN,1012) CSFAC
1012 FORMAT (F7.4)
      READ (IIN,8301) ALAT,DECL,ASC,AEC,SDF,IBHR
8301 FORMAT (F5.2,F6.2,F5.0,F6.3,F6.3,I3)
      ALAT = ALAT*3.1416/180.
      DECL = DECL*3.1416/180.
      CALL CSCALE(MASS,CSFAC)
      WRITE (IOUT,8200)
8200 FORMAT (1H1,50X,' ***INPUT SUMMARY***')
      WRITE (IOUT,8201)
8201 FORMAT (1H0,2X,' NODE',8X,'ISER',1X,'IEX',2X,'IPMP',5X,'DIA',10X,

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1 'LONG',11X,'MASS',12X,'AU',10X,'CAP',8X,'RHO',9X,'MU')
  DO 8010 K=1,3
  IF (K-2) 8001,8002,8002
    8001 LIM = 1
    GO TO 8003
    8002 LIM = LS
    8003 DO 8009 L=1,IIM
      IF (K-2) 8004,8005,8006
        8004 NLIM = NH
        GO TO 8007
        8005 NLIM = ND(L)
        GO TO 8007
        8006 NLIM = NB(L)
        8007 DO 8008 N=1,NLIM
          COND(K,L,N) = 0.0
          CONV(K,L,N) = 0.0
          BMAS(K,L,N) = 0.0
          DMAS(K,L,N) = 1.0
          WRITE (IOUT,8202) K,L,N,ISER(K,L,N),IEX(K,L,N),IPMP(K,L,N),
            1 DIA(K,L,N),LONG(K,L,N),MASS(K,L,N),AUF(K,L,N),CAP(K,L,N),
            2 RHO(K,L,N),MU(K,L,N)
          8202 FORMAT (3I3,4X,3I5,4X,F7.4,4X,E11.4,4X,E11.4,4X,F7.4,4X,
            1 F7.3,4X,F7.3)
          CONTINUE
          8008 CONTINUE
          8009 CONTINUE
          8010 CONTINUE
          WRITE (IOUT,8214)
          8214 FORMAT (1H0,20X,' EXCHANGER',15X,'SUPPLY NODE',10X,'DEMAND NODE',
            1 10X,'TUBES')
          DO 8015 IX=1,NEXCH
            WRITE (IOUT,8215) IX,K1(IX),L1(IX),N1(IX),K2(IX),L2(IX),N2(IX),
              1 NTB(IX)
            8215 FORMAT (1H ,24X,I2,21X,3(I2,1X),12X,3(I2,1X),10X,I5)
            8015 CONTINUE
            WRITE (IOUT,8203)
            8203 FORMAT (1H0,3X,' HVO',13X,'CVO',11X,'THW',9X,'THG',9X,'TCG',11X,

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1  'MGAS', 9X, 'CAPG', 9X, 'TAMB', 8X, 'DTIME')
WRITE (IOUT,8204) HVO,CVO,THW,THG,TCG,NGAS,CAPG,TAMB,DTIME
8204  FORMAT (E11.4,5X,E11.4,5X,F7.2,5X,F7.2,5X,E11.4,5X,F7.4,
1  5X,F7.2,5X,F8.5)
WRITE (IOUT,8205)
8205  FORMAT (1H0,' TYPE',12X,'AW',10X,'RTW',8X,'AWD',10X,'RTWD',8X,'AR',
1  10X,'RTR',9X,'AF',10X,'RTP',10X,'HEIGHT')
DO 8011 N=1,NTYPE
WRITE (IOUT,8206) N,AW(N),RTW(N),AWD(N),RTWD(N),AR(N),RTR(N),
1  AF(N),RTP(N),BH(N)
8206  FORMAT (2X,I2,6X,4(3X,F10.2,6X,F5.2),4X,F10.2)
8011  CONTINUE
WRITE (IOUT,82061)
82061  FORMAT (1H0,' TYPE',9X,'DOOR CRACK',8X,'C',8X,'N',9X,'WINDOW CRACK',
1  1X,8X,'C',8X,'N',9X,'WALL AREA',8X,'C',8X,'N')
DO 80111 N=1,NTYPE
WRITE (IOUT,82062) N,DCL(N),DINC(N),DINN(N),WDCL(N),WDINC(N),
1  WDINN(N),AW(N),WINC(N),WINN(N)
82062  FORMAT (2X,I2,12X,F7.0,5X,F7.3,2X,F7.3,9X,F7.0,7X,F7.3,2X,F7.3,6X,
1  F10.2,4X,F7.3,2X,F7.3)
80111  CONTINUE
WRITE (IOUT,82063)
82063  FORMAT (1H0,' TYPE',7X,'AINFL',10X,'WDSC',6X,'FWLIT(1)',3X,
1  'FWLIT(2)',3X,'FWLIT(3)',3X,'FWLIT(4)',4X,'PRLIT',6X,'WSAB',7X,
2  'RSAB',7X,'POL')
DO 80112 N=1,NTYPE
WRITE (IOUT,82064) N,AINFL(N),WDSC(N),FWLIT(N,NN),NN=1,5)
1  WSAB(N),RSAB(N),POL(N)
82064  FORMAT (2X,I2,5X,F10.2,2X,8(6X,F5.2),4X,F7.2)
80112  CONTINUE
WRITE (IOUT,8208)
8208  FORMAT (1H0,' EXCHANGER',9X,'BLDG TYPE',9X,'UNITS',9X,'COMP AC',
1  9X,'ABS AC',9X,'RES HT',9X,'HT PUMP',9X,'H2O HT')
DO 8014 L=1,LS
NBOI = NB(L)
DO 8013 N=1,NBOI

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MAIN0216

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      IX = IEX(3,L,N)
      WRITE (IOUT,8209) IX
8209  FORMAT (5X,I2)
      DO 8012 I=1,NTYPE
      WRITE (IOUT,8210) I,NU(IX,I),NCMP(IX,I),NABS(IX,I),NRES(IX,I),
1  NHPM(IX,I),NHWS(IX,I)
8210  FORMAT (23X,I2,13X,I4,11X,I4,11X,I4,12X,I4,11X,I4)
8012  CONTINUE
8013  CONTINUE
8014  CONTINUE
      WRITE (IOUT,82065)
82065  FORMAT (1H,' UNSUPPLIED')
      DO 80141 NN=1,NTYPE
      NAEX = 0
      NCEX = NUEX(NN)
      NPEX = FREXT(NN)*NUEX(NN)
      NPFX = FHPEX(NN)*NUEX(NN)
      NHEX = 0
      WRITE (IOUT,8210) NN,NUEX(NN),NCEX,NAEX,NREX,NPEX,NHEX
80141  CONTINUE
      WRITE (IOUT,8211)
8211  FORMAT (1H0,' COMP AC EFF',16X,'ABS AC EFF',16X,'RES HT EFF',16X,
1  'HT PUMP EFF',16X,'H2O HT EFF')
      WRITE (IOUT,8212) ECMP,EABS,ERES,EHPM,EHWS
8212  FORMAT (5X,F5.2,21X,F5.2,21X,F5.2,21X,F5.2,22X,F5.2)
      WRITE (IOUT,82066)
82066  FORMAT (1H0,' LATITUDE',15X,'SOLAR DECL',15X,'APP SOLAR CONST',
1  15X,'ATM EXT COEF',15X,'SKY DIFF FAC')
      BLAT = ALAT*180./3.1416
      BECL = DECL*180./3.1416
      WRITE (IOUT,82067) BLAT,BECL,ASC,AEC,SDF
82067  FORMAT (2X,F6.2,18X,F6.2,21X,F5.0,23X,F6.3,21X,F6.3)
      WRITE (IOUT,8207) EFF
8207  FORMAT (1H0,' THERMAL/ELECTRIC CONVERSION EFFICIENCY:',F7.4)
      WRITE (IOUT,8213) PSSENS
8213  FORMAT (1H0,' PUMP RESPONSE SENSITIVITY FACTOR:',F5.1)

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MAIN0250
MAIN0251
MAIN0252

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8216 WRITE (IOUT,8216) CSFAC
      FORMAT (1H0,' CASE MASS FLOW INPUT SCALE FACTOR:',F7.4)
      READ (IIN,1013) RTBL,ELBL
1013  FORMAT (2F10.0)
      RTHRM = 3.412E06*RTBL
      WRITE (IOUT,217) RTBL
217  FORMAT (1H0,' REACTOR TOTAL THERMAL POWER OUTPUT:',F6.0,' MW (TH)')
9    READ (IIN,1000) KODE
      IF (KODE-1) 11,12,10
11   READ (IIN,1000) IDES
      READ (IIN,1014) TAIR(25)
      READ (IIN,1014) WV(25)
      READ (IIN,1014) WDIR(25)
      WDIR(25) = WDIR(25)*3.1416/180.
      READ (IIN,1014) ELF(25)
1014  FORMAT (F5.2)
10141 FORMAT (F6.2)
      READ (IIN,1009) (TSB(25,I), I=1,NTYPE)
      READ (IIN,1009) (BUF(25,I), I=1,NTYPE)
      READ (IIN,1009) (WUF(25,I), I=1,NTYPE)
1009  FORMAT (10F7.2)
      KOLP = 0
      TOB = TAIR(25)
      DO 1100 NN=1,NTYPE
      TIB(NN) = TSB(25,NN)
1100  CONTINUE
      QHS = RTHRM-ELF(25)*ELBL*3.412E06
      CALL SET(IDES)
      IF (IERR-1) 9,999,9
12   READ (IIN,1000) NTEMP
      IF (NTEMP-12) 13,13,14
13   READ (IIN,1011) (TAIR(I), I=1,NTEMP)
      READ (IIN,1011) (WV(I), I=1,NTEMP)
      READ (IIN,1011) (WDIR(I), I=1,NTEMP)
      READ (IIN,1011) (ELF(I), I=1,NTEMP)
1011  FORMAT (12F5.2)

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MAIN0253
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 MAIN0280
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10111 FORMAT (12F6.2)
      GO TO 15
14   READ (IIN,1011) (TAIR(I), I=1,12)
      READ (IIN,1011) (TAIR(I), I=13,NTEMP)
      READ (IIN,1011) (WV(I), I=1,12)
      READ (IIN,1011) (WV(I), I=13,NTEMP)
      READ (IIN,1011) (WDIR(I), I=1,12)
      READ (IIN,1011) (WDIR(I), I=13,NTEMP)
      READ (IIN,1011) (ELF(I), I=1,12)
      READ (IIN,1011) (ELF(I), I=13,NTEMP)
      DO 1501 I=1,NTEMP
      READ (IIN,1009) (TSB(I,NN), NN=1,NTYPE)
      WDIR(I) = WDIR(I)*3.1416/180.
1501 CONTINUE
      DO 1502 I=1,NTEMP
      READ (IIN,1009) (BUF(I,NN), NN=1,NTYPE)
1502 CONTINUE
      DO 1503 I=1,NTEMP
      READ (IIN,1009) (WUP(I,NN), NN=1,NTYPE)
1503 CONTINUE
      WRITE (IOUT,208)
      FORMAT (1H1,4X,' ***WEATHER DATA DISTRIBUTION***')
      WRITE (IOUT,209)
      FORMAT (1H0,10X,' TIME',10X,' AIR TEMPERATURE (F)',10X,' WIND VELOCI
1TY (MPH)',10X,' WIND DIRECTION (FROM NORTH)')
      ITIM = IBHR
      BWDIR = WDIR(25)*180./3.1416
      WRITE (IOUT,210) ITIM,TAIR(1),WV(1),BWDIR
      DO 16 I=1,NTEMP
      ITIM = I+IBHR
      BWDIR = WDIR(I)*180./3.1416
      WRITE (IOUT,210) ITIM,TAIR(I),WV(I),BWDIR
210  FORMAT (11X,12,' :00',14X,F6.2,23X,F5.2,23X,F6.2)
16   CONTINUE
      WRITE (IOUT,214)
214  FORMAT (1H1,35X,' ***ELECTRICAL LOAD DISTRIBUTION (EXCLUDING HEAT)

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1****)
215  WRITE (IOUT,215)
      FORMAT (1H0,34X,' TIME',10X,'LOAD (MWE)',10X,'BASE LOAD FRACTION')
      ITIM = IBHR
      ELD = ELF(25)*ELBL
      WRITE (IOUT,216) ITIM,ELD,ELF(25)
216  FORMAT (35X,I2,' :00',8X,F7.1,19X,F5.2)
      DO 1601 I=1,NTEMP
      ITIM = I+IBHR
      ELD = ELF(I)*ELBL
      WRITE (IOUT,216) ITIM,ELD,ELF(I)
1601  CONTINUE
      WRITE (IOUT,2160)
2160  FORMAT (1H1,47X,' ***BUILDING USE FACTORS***')
      WRITE (IOUT,2161)
2161  FORMAT (1H0,' TIME',5X,' 1 2 3 4 5 6 7 8 9
1 10 11 12 13 14 15 16 17 18 19 20')
      ITIM = IBHR
      WRITE (IOUT,2162) ITIM,(BUF(25,NN),NN=1,NTEMP)
2162  FORMAT (1H0,2X,I2,4X,20(F4.2,1X))
      DO 16010 I=1,NTEMP
      ITIM = IBHR+I
      WRITE (IOUT,2163) ITIM,(BUF(I,NN),NN=1,NTEMP)
2163  FORMAT (1H ,2X,I2,4X,20(F4.2,1X))
16010 CONTINUE
      WRITE (IOUT,2164)
2164  FORMAT (1H1,42X,' ***SERVICE HOT WATER USE FACTORS***')
      WRITE (IOUT,2161)
      ITIM = IBHR
      WRITE (IOUT,2162) ITIM,(WUP(25,NN),NN=1,NTEMP)
      DO 16011 I=1,NTEMP
      ITIM = IBHR+I
      WRITE (IOUT,2163) ITIM,(WUP(I,NN),NN=1,NTEMP)
16011 CONTINUE
      WRITE (IOUT,2165)
2165  FORMAT (1H1,42X,' ***BUILDING ROOM TEMPERATURES (F)***')

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 MAIN0360

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WRITE (IOUT,2161)
ITIM = IBHR
WRITE (IOUT,2166) ITIM, (TSB(25, NN), NN=1, NTYPE)
2166 FORMAT (1H0,2X,I2,4X,20F5.0)
DO 16012 I=1, NTEMP
ITIM = IBHR+I
WRITE (IOUT,2167) ITIM, (TSB(I, NN), NN=1, NTYPE)
2167 FORMAT (1H,2X,I2,4X,20F5.0)
16012 CONTINUE
DO 1603 L=1, LS
NBOI = NB(L)
DO 1602 N=1, NBOI
IX = IEX(3, L, N)
TLH(IX) = TO(3, L, N) - 5.0
TUH(IX) = TO(3, L, N) + 5.0
TUL(IX) = TI(3, L, N) + 5.0
1602 CONTINUE
1603 CONTINUE
DO 1605 N=1, NH
IF (IEX(1, 1, N)) 1605, 1605, 1604
1604 IX = IEX(1, 1, N)
TRP(IX) = TO(1, 1, N)
TUF(IX) = TO(1, 1, N) + 5.0
TLP(IX) = TO(1, 1, N) - 5.0
1605 CONTINUE
CALL QLOAD(KODE, NTYPE, TAMB, IOUT)
IF (IDES) 999, 1606, 999
1606 KOLP = 0
CALL DLOAD(KODE, KODP, NHR, IHRL, HRF, IOUT, LS, NB, IEX, NTYPE, NU, TIB, TOB)
TEILD = EIF(25)*ELBI + ETHL(25)/3.412E06
STOR = HVO/1.0E04
STLE = MASS(1, 1, 1) * (CAP(1, 1, 1) * TI(1, 1, 1) - CAP(1, 1, 1) * TO(1, 1, 1, NH)) /
1 3.412E06
RS = RTBL*EFF
WRITE (IPNCH, 8217) RS, EFF
8217 FORMAT (F7.2, F5.2)

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MAIN0386
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MAIN0388
MAIN0389
MAIN0390
MAIN0391
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MAIN0395
MAIN0396

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WRITE (IPNCH,2426) STLD,TELLD,STOR
TIME = 0.0
NTR = NSTEP/NPNT
DO 26 IHR=1,NTEMP
  NHR = IHR
  HRP = 0.0
  IHRL = IHR-1
  IF (IHRL) 17,17,18
  IHRL = 25
  DO 25 ITR=1,NTR
    DO 24 NTI=1,NPNT
      TIME = TIME+DTIME
      HRF = HRP+DTIME
      TOB = TAIR(IHRL)+HRF*(TAIR(IHR)-TAIR(IHRL))
      ESCL = ETHL(IHRL)+HRF*(ETHL(IHR)-ETHL(IHRL))
      TIBM = 0.0
      DO 1802 NN=1,NTYPE
        TIB(NN) = TSB(IHRL,NN)+HRF*(TSB(IHR,NN)-TSB(IHRL,NN))
        IF (TIB(NN)-TIBM) 1802,1802,1801
      TIBM = TIB(NN)
    CONTINUE
    DO 18022 L=1,LS
      NBOI = NB(L)
      DO 18021 N=1,NBOI
        IX = IEX(3,L,N)
        TO(IX) = TOL(IHRL,IX)+HRF*(TOL(IHR,IX)-TOL(IHRL,IX))
      CONTINUE
    CONTINUE
    TELLD = ((ELF(IHRL)+HRF*(ELF(IHR)-ELF(IHRL)))*ELBL*3.412E06)+ESCL
    QHS = RTHRM - TELLD
    RESIZ = TELLD/(EFF*3.412E06)
    IF (QHS) 1803,1803,1804
    REFF = EFF
    QHS = 10.0
    GO TO 1805
  1804 REFF = TELLD/RTHRM

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1805 MGAS = QHS/(CAPG*(THG-TCG))
19   IFIO = 1
    CALL FLOWS
    IF (IERR-1) 2000,999,2000
2000 JEM = 0
    DO 22 L=1,LS
      NECI = NB(L)
      DO 21 N=1,NBOI
        IX = IEX(3,L,N)
        TIE = TO(3,L,N)-TQ(IX)/(MASS(3,L,N)*CAP(3,L,N))
        IF (TIP-TIBM) 2001,2001,2002
2001 TI(3,L,N) = TIBM
        MASS(3,L,N) = TQ(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))
        JEM = 1
        GO TO 2100
2002 IF (TIP-TUL(IX)) 2004,2003,2003
2003 TI(3,L,N) = TUL(IX)
        MASS(3,L,N) = TQ(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))
        JPM = 1
        GO TO 2100
2004 TI(3,L,N) = TIP
2100 IF (TO(3,L,N)-TLH(IX)) 2101,2101,2102
2101 TO(3,L,N) = TLH(IX)
        MASS(3,L,N) = TO(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))
        JPM = 1
        GO TO 21
2102 IF (TO(3,L,N)-TUH(IX)) 21,2103,2103
2103 TO(3,L,N) = TUH(IX)
        MASS(3,L,N) = TO(IX)/(CAP(3,L,N)*(TO(3,L,N)-TI(3,L,N)))
        JPM = 1
21   CONTINUE
22   CONTINUE
    DO 2203 N=1,NH
      IF (IEX(1,1,N)) 2203,2203,2201
2201 IX = IEX(1,1,N)
      IF (TI(1,1,N+1)-TUP(IX)) 2204,2202,2202

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MAIN0433
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 MAIN0460
 MAIN0461
 MAIN0462
 MAIN0463
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 MAIN0465
 MAIN0466
 MAIN0467
 MAIN0468

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2204 IF (TI(1,1,N+1)-TLP(IX)) 2202,2202,2203
2202 JPM = 1
2203 CONTINUE
2005 IF (JPM-1) 24,2005,24
      DO 2006 IX=1,NEXCH
      KE = K2(IX)
      LE = L2(IX)
      NE = N2(IX)
      K = K1(IX)
      L = L1(IX)
      N = N1(IX)
      AMAS(K,L,N) = (MASS(KE,LE,NE)*CAP(KE,LE,NE)*TO(KE,LE,NE) -
1 TI(KE,LE,NE)))/(CAP(K,L,N)*TI(K,L,N)-TO(K,L,N))
      IF (AMAS(K,L,N)) 2007,2007,2006
2007 AMAS(K,L,N) = MASS(K,L,N)
2006 CONTINUE
      DO 2014 L=1,LS
      NLIM = ND(L)
      AMS(L) = 0.0
      DO 2013 N=1,NLIM
      IF (IEX(2,L,N)) 2013,2013,2011
2011 IF (ISER(2,L,N)) 2013,2013,2012
2012 AMS(L) = AMS(L)+AMAS(2,L,N)
2013 CONTINUE
2014 CONTINUE
      DO 2017 L=1,IS
      NLIM = ND(L)
      DO 2016 N=1,NLIM
      IF (ISER(2,L,N)) 2015,2015,2016
2015 AMAS(2,L,N) = AMS(L)
2016 CONTINUE
2017 CONTINUE
      RMAS = 0.0
      DO 2021 N=1,NH
      IF (IEX(1,1,N)) 2021,2021,2018
2018 IX = IEX(1,1,N)

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MAIN0505
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MAIN0540

KE = K2(IX)
LE = L2(IX)
NE = N2(IX)
AMAS(1,1,N) = MASS(1,1,N-1)
DMAS(1,1,N) = (AMAS(KE,LE,NE)*CAP(KE,LE,NE)*(TO(KE,LE,NE) -
1 TI(KE,LE,NE)))/(CAP(1,1,N)*(TI(1,1,N)-TRP(IX)))
IF (DMAS(1,1,N)) 2261,2261,2262
2261 DMAS(1,1,N) = 10.0
2262 AMAS(1,1,N) = DMAS(1,1,N)
IF (AMAS(1,1,N)-RMAS) 2021,2263,2263
2263 RMAS = AMAS(1,1,N)
2021 CONTINUE
IF (RMAS) 2022,2022,2023
2022 RMAS = 10.0
2023 DO 2024 N=1,NH
2024 AMAS(1,1,N) = RMAS
CONTINUE
DO 2310 N=1,NH
IF (IEX(1,1,N)) 2310,2310,2301
2301 EMAS(1,1,N) = AMAS(1,1,N)-DMAS(1,1,N)
IF (EMAS(1,1,N)) 2302,2302,2303
2302 EMAS(1,1,N) = 0.0
DMAS(1,1,N) = AMAS(1,1,N)
2303 X RAT = DMAS(1,1,N)/AMAS(1,1,N)
MASS(1,1,N) = X RAT*MASS(1,1,N-1)
AMAS(1,1,N) = DMAS(1,1,N)
2310 CONTINUE
CALL SET(IDES)
IF (IERR-1) 24,999,24
24 CONTINUE
T = TIME+IBHR
CALL PRV(T,THW,TCW,HVO,CVO,QHW,QCW,THG,TCG,MGAS,CAPG,PHF,THI,PEX,
1 NPMP)
CODE = 1
CALL DLOAD(KODE,KODP,NHR,IHRL,HRF,IOUT,LS,NR,IEX,NTYPE,NU,TIB,TOB)
OTLD = 0.0

```



```

DO 2401 NX=1,NEXCH
  KD = K2(NX)
  IF (KD-2) 2401,2401,2400
2400  OTLD = OTLD + TQ(NX)
2401  CONTINUE
      OTLD = OTLD/3.412E06
      WRITE (IOUT,2423) OTLD
2423  FORMAT (1H0,' ***TOTAL CONSUMER HEAT DEMAND:',F8.2,' MW(TH) (THERM
1AL DISTRIBUTION SYSTEM LOAD)***')
      ELB = TELD/3.412E06
      WRITE (IOUT,218) ELD
218   FORMAT (1H0,' ***TOTAL SYSTEM ELECTRICAL LOAD:',F8.2,' MW(E) (INCL
1UDING SPACE CONDITIONING)***')
      WRITE (IOUT,2424) EFF,RRSIZ
2424  FORMAT (1H0,' ***MINIMUM REQUIRED REACTOR SIZE FOR EFFICIENCY OF',
1 F5.2,' IS',F7.2,' MWT (TO SUPPLY ELECTRICAL LOAD ONLY)***')
      WRITE (IOUT,2425) RTBL,REFF
2425  FORMAT (1H0,' ***REQUIRED EFFICIENCY FOR REACTOR SIZE OF',F7.2,
1 ' MWT IS',F5.2,' (TO SUPPLY ELECTRICAL LOAD ONLY)***')
      STOR = HVO/1.0E04
      STLD = MASS(1,1,1)*(CAP(1,1,1)*TI(1,1,1)-CAP(1,1,1,NH))/
1 3.412E06
      WRITE (IPNCH,2426) STLD,ELD,STOR
2426  FORMAT (3(F8.2,3X))
      WRITE (IOUT,2420)
2420  FORMAT (1H1,47X,' **EXCHANGER HEAT BALANCE**')
      WRITE (IOUT,2421)
2421  FORMAT (1H0,30X,' EXCHANGER',10X,' SUPPLY (BTU/HR)',10X,' DEMAND (BT
1U/HR)',10X,' DIFFERENCE')
      DO 2402 NX=1,NEXCH
        K = K2(NX)
        IK = K1(NX)
        L = L2(NX)
        IL = L1(NX)
        N = N2(NX)
        IN = N1(NX)

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MAIN0576

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2422 OD = MASS(K,L,N)*CAP(K,L,N)*(TO(K,L,N)-TI(K,L,N))
2402 OS = MASS(IK,IL,IN)*CAP(IK,IL,IN)*(TI(IK,IL,IN)-TO(IK,IL,IN))
25 QDIF = OS-QD
26 WRITE (IOUT,2422) NX,OS,QD,QDIF
27 FORMAT (1H,34X,I2,15X,E11.4,14X,E11.4,12X,E11.4)
211 CONTINUE
26 CONTINUE
27 CONTINUE
211 WRITE (IOUT,211)
211 FORMAT (1H1,' **ANALYSIS COMPLETED FOR GIVEN TEMPERATURE DISTRIBUTI
ION**')
READ (IIN,1000) CODE
IF (CODE-1) 11,28,10
28 WRITE (IOUT,212)
212 FORMAT (1H0,' **ANALYSIS CONTINUING FOR NEW TEMPERATURE DISTRIBUTI
ON**')
TAIR(25) = TAIR(NTEMP)
ELF(25) = ELF(NTEMP)
DO 2801 NN=1,NTYPE
TSB(25,NN) = TSB(NTEMP,NN)
2801 CONTINUE
GO TO 12
10 WRITE (IOUT,200)
200 FORMAT (1H,' **TERMINATION CODE READ**')
999 WRITE (IOUT,213)
213 FORMAT (1H1,' ***PROGRAM TERMINATED***')
STOP
END

```

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MAIN0577
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CSCA0001
 CSCA0002
 CSCA0003
 CSCA0004
 CSCA0005
 CSCA0006
 CSCA0007
 CSCA0008
 CSCA0009
 CSCA0010
 CSCA0011
 CSCA0012

```

SUBROUTINE CSCALE(MASS,CSPAC)
  REAL MASS
  DIMENSION MASS(3,5,13)
  DO 3 K=1,3
  DO 2 L=1,5
  DO 1 N=1,13
    MASS(K,L,N) = MASS(K,L,N)*CSPAC
  CONTINUE
  CONTINUE
  CONTINUE
  RETURN
  END

```

1
2
3

QLOD0001
QLOD0002
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QLOD0012
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QLOD0031
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QLOD0034
QLOD0035
QLOD0036

```

SUBROUTINE QLOAD(KODE,NTYPE,TAMB,IOUT)
  DIMENSION BH(20),TAIR(25),TSR(25,20),WV(25),WDIR(25),WA(20),X(4)
  DIMENSION AW(20),AINFL(20),QLEAK(20),QWDSG(20),DSI(5)
  DIMENSION DFSI(5),CTH(5),FWLIT(20,5),T(6),A(6),AWD(20),WDSC(20)
  DIMENSION QCOND(20),MTW(20),MTR(20),WHTCA(6),WHTCB(6),WHTCC(6)
  DIMENSION RTW(20),RTWD(20),AR(20),RTP(20),WSAB(20),RSAB(20),AF(20)
  DIMENSION RTF(20),POL(20),BUF(25,20),QLIG(20),QL(25,20)
  DIMENSION DCL(20),DINC(20),DINN(20),WDCL(20),WDINC(20),WDINN(20)
  DIMENSION WINC(20),WINN(20)
  COMMON /BLD/AW,RTW,AWD,RTWD,AR,RTR,AF,RTF,MTW,MTR,BH,AINFL
  COMMON /BLD/WSAB,RSAB,POL,WV,WDIR,IBHR,ALAT,DECL
  COMMON /BLD/ASC,AEC,SDF,BUF,WA,WDSC,FWLIT
  COMMON /ALD/OL,NTEMP,TAIR,TSB
  COMMON /INFP/DCL,DINC,DINN,WDCL,WDINC,WDINN,WINC,WINN
  DATA T/-.00885,2.71235,-.62062,-7.07329,9.75995,-3.89922/
  DATA A/.01154,.77674,-3.94657,8.57881,-8.38135,3.01188/
  DATA WHTCA/0.0,.001,0.0,-.002,0.0,-.00125/
  DATA WHTCB/.464,.320,.330,.315,.244,.262/
  DATA WHTCC/2.04,2.20,1.90,1.45,1.80,1.45/
  WRITE(IOUT,1000)
1000  FORMAT(1H1,'TIME',4X,'BUILDING',6X,'CONDUCTION',5X,'INFILTRATION
      1',4X,'WINDOW SOLAR',6X,'LIGHTING',7X,'TOTAL LOAD')
      IF (KODE-1) 1,2,39
1      IBEG = 25
      IEND = 25
      GO TO 3
2      IBEG = 1
      IEND = NTEMP
3      DO 38 IHR=IBEG,IEND
        DO 16 I=1,NTYPE
          TOAB = TAIR(IHR)+460.
          TIAB = TSB(IHR,I)+460.
          PC = 5.3508*BH(I)*(1.0/T CAB-1.0/TIAB)
          PV = .000482*WV(IHR)**2
          X(1) = WDIR(IHR)-WA(I)
          X(2) = X(1)-1.5708

```

```

4      X(3) = X(1)-3.1416
      X(4) = X(1)-4.7124
      ALEAK = 0.0
      DO 14 N=1,4
      IF (ABS(X(N))-4.7124) 7,4,4
      IF (X(N)) 5,5,6
5      X(N) = 6.2832+X(N)
      GO TO 8
6      X(N) = 6.2832-X(N)
      GO TO 8
7      IF (ABS(X(N))-1.5708) 8,8,9
8      IF (ABS(X(N))-0.7854) 10,10,11
9      ETKN = -0.35
      PTKO = 1.0
      GO TO 12
10     PTKN = 0.6
      ETKO = COS(X(N))
      GO TO 12
11     ETKN = -0.7
      PTKO = COS(X(N))
      PW = PTKN*PTKO*PV
12     PT = ABS(PW) + ABS(PC)
      IF (PT-1.0E-06) 14,14,13
13     DLK = DCL(I)*DINC(I)*EXP(DINN(I)*ALOG(PT))/4.0
      WDLK = WDCI(I)*WDINC(I)*EXP(WDINN(I)*ALOG(PT))/4.0
      WLK = AW(I)*WINC(I)*EXP(WINN(I)*ALOG(PT))/8.0
      ALEAK = ALEAK+DLK+WDLK+WLK
14     CONTINUE
      ALEAK = ALEAK*60.
      VLEAK = AINFL(I)*BUP(IHR,I)*60.
      IF (ALEAK-VLEAK) 15,15,1501
15     ALEAK = VLEAK
1501    OLEAK(I) = 0.018*ALEAK*(TSB(IHR,I)-TAIR(IHR))
16     CONTINUE
      IF (KODE-1) 17,18,39
17     ITIM = IBHR

```

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QLOD0037
QLOD0038
QLOD0039
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QLOD0041
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QLOD0064
QLOD0065
QLOD0066
QLOD0067
QLOD0068
QLOD0069
QLOD0070
QLOD0071
QLOD0072

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18      GO TO 19
      ITIM = IHR+IBHR
      IF (ITIM-24) 19,1801,1801
1801    ITIM = ITIM-24
19      H = .2618*(ITIM-12)
      CZ = SIN(ALAT)*SIN(DECL)+COS(ALAT)*COS(DECL)*COS(H)
      CW = COS(DECL)*SIN(H)
      IF (1.0-CW**2-CZ**2) 1901,1901,1902
1901    CS = 0.0
      GO TO 21
1902    CS = EXP(0.5*ALOG(1.0-CW**2-CZ**2))
      IF (COS(H)-TAN(DECL)/TAN(ALAT)) 20,20,21
20      CS = -CS
21    DO 35 I=1,NTYPE
      IF (COS(H)+TAN(DECL)*TAN(ALAT)) 22,22,23
22    OWESG(I) = 0.0
      DO 2201 NN=1,4
      LSI(NN) = 0.0
      DSI(NN) = 0.0
2201    CONTINUE
      DSIR = 0.0
      DFSIR = 0.0
      GO TO 33
23    DNSI = ASC/EXP(-AEC/CZ)
      SWA = WA(I)-3.1416
      CTH(1) = SIN(SWA)*CW+COS(SWA)*CS
      CTH(2) = SIN(SWA+1.5708)*CW+COS(SWA+1.5708)*CS
      CTH(3) = SIN(SWA+3.1416)*CW+COS(SWA+3.1416)*CS
      CTH(4) = SIN(SWA+4.7124)*CW+COS(SWA+4.7124)*CS
      CTH(5) = CZ
      DO 26 NN=1,5
      IF (CTH(NN)) 25,25,24
24    LSI(NN) = (DNSI*CTH(NN))*FWLIT(I,NN)
      GO TO 26
25    DSI(NN) = 0.0
26    CONTINUE

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QLOD0073
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QLOD0101
QLOD0102
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QLOD0106
QLOD0107
QLOD0108


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27 DSIR = DSI(5)
DO 30 NN=1,4
IF (CTH(NN)+0.2) 27,27,28
Y = 0.45
GO TO 29
28 Y = 0.55+0.437*CTH(NN)+0.313*CTH(NN)**2
29 DFI(NN) = DSI*(SDF*Y+0.1*(SDF+C2))*FWLIT(I,NN)
30 CONTINUE
DFIR = SDF*DSI*FWLIT(I,5)
WSGF = 0.0
DO 32 NN=1,4
FAC1 = 0.0
FAC2 = 0.0
FAC3 = 0.0
FAC4 = 0.0
DO 31 N=1,6
J = N
FAC1 = FAC1+T(J)*CTH(NN)**(J-1)
FAC2 = FAC2+T(J)/(J+1)
FAC3 = FAC3+A(J)*CTH(NN)**(J-1)
FAC4 = FAC4+A(J)/(J+1)
CONTINUE
31 SHGF = DSI(NN)*FAC1+2.0*DFI(NN)*FAC2+0.267*(DSI(NN)*FAC3+
1 2.0*DFI(NN)*FAC4)
WSGF = WSGF+SHGF
CONTINUE
32 QWDSG(I) = AWD(I)/4.0*WSGF*WDSC(I)
33 QCOND(I) = 0.0
WHO = 1.0/(WHTCA(MTW(I))*WV(IHR)**2+WHTCB(MTW(I))*WV(IHR)+
1 WHTCC(MTW(I)))
RUC = 1.0/(WHTCA(MTR(I))*WV(IHR)**2+WHTCB(MTR(I))*WV(IHR)+
1 WHTCC(MTR(I)))
AUW = AW(I)/4.0*(1.0/(RTW(I)+WHO))+AWD(I)/4.0*(1.0/RTWD(I))
AUR = AR(I)/(RTR(I)+RHO)
DO 34 NN=1,4
TSAW = TAIR(IHR)*WSAB(I)*(DSI(NN)+DFI(NN))*WHO

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QLOD0109
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34  QCOND(I) = QCOND(I)+AUW*(TSB(IHR,I)-TSAW)
    CONTINUE
    TSAR = TAIR(IHR)+RSAB(I)*(DSIR+DFSIR)*RHO
    QCOND(I) = QCOND(I)+AUR*(TSR(IHR,I)-TSAR)
    AUG = AF(I)/RTF(I)
    QCOND(I) = QCOND(I)+AUG*(TSB(IHR,I)-(TSB(IHR,I)+TAMB)/2.0)
    CONTINUE
    DO 36 I=1,NTYPE
      OLIG(I) = POL(I)*BUF(IHR,I)*3412.
    CONTINUE
    DO 37 I=1,NTYPE
      QL(IHR,I) = QCOND(I)+QLEAK(I)-QWDSG(I)-OLIG(I)
      WRITE (IOUT,1001) IHR,I,QCOND(I),QLEAK(I),QWDSG(I),OLIG(I),
1      QL(IHR,I)
1001 FORMAT (3X,I2,8X,I2,8X,5(E11.4,5X))
37  CONTINUE
    WRITE (IOUT,1002)
1002 FORMAT ('H ',' ')
38  CONTINUE
39  RETURN
    END.

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DLOD0001
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 DLOD0035
 DLOD0036

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SUBROUTINE DLOAD(KODE,KODP,IHR,IHRL,HRF,IOUT,LS,NB,IEX,NTYPE,NU,
1 TIB,TOR)
  DIMENSION ETHL(25),NB(5),IEX(3,5,13),TOL(25,31),NU(31,20)
  DIMENSION QL(25,20),NCMP(31,20),NABS(31,20),NRES(31,20)
  DIMENSION NHFM(31,20),NHWS(31,20),NUEX(20),FREXT(20),FHPEX(20)
  DIMENSION TIB(20),TAIR(25),TSB(25,20),DHW(20),WUF(25,20)
  COMMON /DLD/ETHL,TOL,NCMP,NABS,NRES,NHFM,NHWS,ECMP,EABS,ERES,EHFM
  COMMON /DLD/EHWS,NUEX,FREXT,FHPEX,DHW,WUF
  COMMON /ALD/QL,NTEMP,TAIR,TSR
  TLD = 0.0
  TEID = 0.0
  TTLD = 0.0
  IF (KODE-1) 999,1000,24
999  IBEG = 25
    IEND = 25
    GO TO 1001
1000  IBEG = 1
    IEND = NTEMP
  IF (KODE-1) 2,1,2
1  WRITE (IOUT,200)
200  FORMAT (1H1,41X,' ***CONSUMER ENERGY DEMAND BREAKDOWN***')
    WRITE (IOUT,201)
201  FORMAT (1H2,1X,' SUPPLY',5X,'BUILDING',6X,'ROOM',7X,'NUMBER OF',
    1 3X,'AIR CONDITIONING DEMAND (BTU/HR)',6X,'TOTAL HEATING DEMAND (B
    2TU/HR)')
    WRITE (IOUT,202)
202  FORMAT (1H,' EXCHANGER',5X,'TYPE',5X,'TEMPERATURE',5X,'UNITS',5X,
    1 'ABSORPTIVE',11X,'COMPRESSIVE',3X,'RESISTANCE',3X,'HEAT PUMPS',
    2 3X,'HOT WATER')
    NHR = IHR
    NHRL = IHRL
    AHRF = HRF
    GO TO 3
2  DO 23 NHR=IBEG,IEND
    ETHL(NHR) = 0.0
    NHFL = NHR
  
```



```

3      AHRF = 1.0
      DO 15 L=1,LS
      NDOI = NB(I)
      DC 14 N=1,NDOI
      IX = IEX(3,I,N)
      IF (KODP-1) 4,5,4
4      TOL(NHR,IX) = 0.0
      TLD = 0.0
      TELD = 0.0
      TTLD = 0.0
      DO 12 NN=1,NTYPE
      IF (NU(IX,NN)) 12,12,6
5      OCMP = 0.0
      OADS = 0.0
      ORES = 0.0
      OHPM = 0.0
      OHWS = 0.0
      O = NU(IX,NN)*(QL(NHRL,NN)+AHRF*(QL(NHR,NN)-QL(NHRL,NN)))
      TOAB = TAIR(NHRL)+AHRF*(TAIR(NHR)-TAIR(NHRL))+460.
      TIAB = TSB(NHRL,NN)+AHRF*(TSB(NHR,NN)-TSB(NHRL,NN))+460.
      ODHW = NU(IX,NN)*DHW(NN)*(WUF(NHRL,NN)+AHRF*(WUF(NHR,NN)-
1      WUF(NHRL,NN)))
      IF (O) 7,8,8
7      O = -O
      IF (TOAB/TIAB-(1.0+1.0E-06)) 7001,7001,7002
7001  BADC = 1.0E10
      O = 0.0
      GO TO 7003
7002  EADC = .028037/(TOAB/TIAB-1.0)
7003  ECMP = BADC*ECMP
      EABS = BADC*EABS
      CCMP = NCMP(IX,NN)*(O/BCMP)/(NCMP(IX,NN)+NABS(IX,NN))
      OABS = NABS(IX,NN)*(O/BABS)/(NCMP(IX,NN)+NABS(IX,NN))
      GO TO 9
8      IF ((1.0-1.0E-06)-TOAB/TIAB) 8001,8001,8002
8001  EADH = 1.0E10

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DLOD0037
DLOD0038
DLOD0039
DLOD0040
DLOD0041
DLOD0042
DLOD0043
DLOD0044
DLOD0045
DLOD0046
DLOD0047
DLOD0048
DLOD0049
DLOD0050
DLOD0051
DLOD0052
DLOD0053
DLOD0054
DLOD0055
DLOD0056
DLOD0057
DLOD0058
DLOD0059
DLOD0060
DLOD0061
DLOD0062
DLOD0063
DLOD0064
DLOD0065
DLOD0066
DLOD0067
DLOD0068
DLOD0069
DLOD0070
DLOD0071
DLOD0072

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```

      O = 0.0
      GO TO 8003
8002  BADH = .068182/(1.0-TOAB/TIAB)
8003  BHPM = BACH*BHPM
8004  IF (BHPM-ERES) 8004,8004,8005
      ORES = (NRES(IX,NN)+NHPM(IX,NN))*(O/ERES)/(NRES(IX,NN)+
1 NHPM(IX,NN)+NHWS(IX,NN))
      OHWS = NHWS(IX,NN)*(O/EHWS)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN))
      GO TO 9
8005  ORES = NRES(IX,NN)*(O/ERES)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN))
      QHPM = NHPM(IX,NN)*(Q/BHPM)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN))
      QHWS = NHWS(IX,NN)*(Q/EHWS)/(NRES(IX,NN)+NHPM(IX,NN)+NHWS(IX,NN))
      ORES = ORES+(NRES(IX,NN)+NHPM(IX,NN))*(QDHW/ERES)/(NRES(IX,NN)+
1 NHPM(IX,NN)+NHWS(IX,NN))
      OHWS = OHWS+NHWS(IX,NN)*(QDHW/EHWS)/(NRES(IX,NN)+NHPM(IX,NN)+
1 NHWS(IX,NN))
      TLD = TLD+Q+QDHW
      TTLD = TELD+QCOMP+QRES+QHPM
      TTLD = TTLD+QABS+QHWS
      IF (KODP-1) 12,10,12
10    QABS = QABS*BABS
      QCOMP = QCOMP*BCMP
      QRES = QRES*ERES
      QHPM = QHPM*BHPM
      OHWS = OHWS*EHWS
      WRITE (IOUT,206) IX,NN,TIB(NN),NU(IX,NN),QABS,QCOMP,QRES,QHPM,QHWS
206  FORMAT (5X,I2,10X,I2,8X,F6.2,8X,I4,4X,E11.4,10X,E11.4,3X,E11.4,2X,
1 E11.4,1X,E11.4)
12  CONTINUE
      IF (KODP-1) 13,14,13
13  TOL(NHR,IX) = TTLD
      IF (TOL(NHR,IX)-100.) 1301,1301,1302
1301 TOL(NHR,IX) = 100.
1302 ETHL(NHR) = ETHL(NHR)+TELD
14  CONTINUE
15  CONTINUE
DLOD0073
DLOD0074
DLOD0075
DLOD0076
DLOD0077
DLOD0078
DLOD0079
DLOD0080
DLOD0081
DLOD0082
DLOD0083
DLOD0084
DLOD0085
DLOD0086
DLOD0087
DLOD0088
DLOD0089
DLOD0090
DLOD0091
DLOD0092
DLOD0093
DLOD0094
DLOD0095
DLOD0096
DLOD0097
DLOD0098
DLOD0099
DLOD0100
DLOD0101
DLOD0102
DLOD0103
DLOD0104
DLOD0105
DLOD0106
DLOD0107
DLOD0108

```

```

DO 21 NN=1, NTYPE
  IF (NUEX(NN)) 21, 21, 1501
1501  OCIXT = 0.0
      OREXT = 0.0
      OHEXT = 0.0
      OAEXT = 0.0
      OHWEX = 0.0
      OEXT = NUEX(NN) * (QL(NHRL, NN) + AHRF * (QL(NHR, NN) - QL(NHRL, NN)))
      TOAB = TAIR(NHRL) + AHRF * (TAIR(NHR) - TAIR(NHRL)) + 460.
      TIAB = TSB(NHRL, NN) + AHRF * (TSB(NHR, NN) - TSB(NHRL, NN)) + 460.
      CDEXT = NUEX(NN) * DHW(NN) * (WUP(NHRL, NN) + AHRF * (WUP(NHR, NN) -
1      WUP(NHRL, NN)))
      IF (OEXT) 16, 17, 17
16    OEXT = -OEXT
      IF (TOAB/TIAB - (1.0 + 1.0E-06)) 1601, 1601, 1602
1601  BADC = 1.0E10
      OEXT = 0.0
      GO TO 1603
1602  BADC = .028037 / (TOAB/TIAB - 1.0)
1603  BCMP = BADC * ECMP
      OEXT = OEXT / BCMP
      GO TO 18
17    IF ((1.0 - 1.0E-06) - TOAB/TIAB) 1701, 1701, 1702
1701  BADH = 1.0E10
      OEXT = 0.0
      GO TO 1703
1702  BADH = .068182 / (1.0 - TOAB/TIAB)
1703  BHEM = BADH * EHPM
      IF (BHEM - ERES) 1704, 1704, 1705
1704  QREXT = (OEXT / ERES) * (PREXT(NN) + FHPEX(NN))
      OHWEX = (1.0 - PREXT(NN)) - FHPEX(NN) * (OEXT / ERES)
      GO TO 18
1705  QREXT = (OEXT / ERES) * PREXT(NN)
      OHEXT = (OEXT / BHEM) * FHPEX(NN)
      OHWEX = (1.0 - PREXT(NN)) - FHPEX(NN) * (OEXT / ERES)
      QREXT = QREXT + (QDEXT / ERES) * (PREXT(NN) + FHPEX(NN))
18

```

```

DLOD0109
DLOD0110
DLOD0111
DLOD0112
DLOD0113
DLOD0114
DLOD0115
DLOD0116
DLOD0117
DLOD0118
DLOD0119
DLOD0120
DLOD0121
DLOD0122
DLOD0123
DLOD0124
DLOD0125
DLOD0126
DLOD0127
DLOD0128
DLOD0129
DLOD0130
DLOD0131
DLOD0132
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DLOD0134
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DLOD0137
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DLOD0139
DLOD0140
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DLOD0142
DLOD0143
DLOD0144

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19  QHWEX = QHWEX+(QDEXT/EHWS)*(1.0-FREXT(NN)-PHPEX(NN))
    IF (KODP-1) 20,19,20
    TLD = TLD+QEXT+QDEXT
    TELD = TELD+QEXT+QREXT+QHEXT
    QAEXT = QAEXT+BABS
    QCEXT = QCEXT+BCMP
    CREXT = CREXT+ERES
    QHEXT = QHEXT+RHPM
    QHWEX = QHWEX+EHWS
    WRITE (IOUT,207) NN,TIB(NN),NUEX(NN),QAEXT,QCEXT,QREXT,QHEXT,QHWEX
    FORMAT (1H,3X,'NONE',9X,I2,8X,F6.2,8X,I4,4X,E11.4,10X,E11.4,3X,
1  E11.4,2X,E11.4,1X,E11.4)
    GO TO 21
20  ETHL(NHR) = ETHL(NHR)+QCEXT+QREXT+QHEXT
21  CONTINUE
22  IF (KODP-1) 23,22,23
23  WRITE (IOUT,208) TOB
24  FORMAT (1H0,' ***OUTSIDE AIR TEMPERATURE:',F7.2,' F***')
    TLE = TLD/3.412E06
    WRITE (IOUT,209) TLD
25  FORMAT (1H0,' ***TOTAL COMMUNITY SPACE CONDITIONING & DOMESTIC HOT
1  WATER LOAD:',F8.2,' MW(TH)***')
    TELD = TELD/3.412E06
    WRITE (IOUT,210) TELD
26  FORMAT (1H0,' ***TOTAL ELECTRIC SPACE CONDITIONING & DOMESTIC HOT
1  WATER DEMAND:',F8.2,' MW(E)***')
    GO TO 24
27  CONTINUE
28  RETURN
29  END
DLOD0145
DLOD0146
DLOD0147
DLOD0148
DLOD0149
DLOD0150
DLOD0151
DLOD0152
DLOD0153
DLOD0154
DLOD0155
DLOD0156
DLOD0157
DLOD0158
DLOD0159
DLOD0160
DLOD0161
DLOD0162
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DLOD0164
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DLOD0169
DLOD0170
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DLOD0172
DLOD0173
DLOD0174

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SUBROUTINE STDY(MASS, TI, TO, N1, N2, AUF, TAMB, IERR, KODE)
REAL MASS
DIMENSION IEX(3,5,13), MASS(3,5,13), TI(3,5,13), TO(3,5,13)
DIMENSION AUF(3,5,13), CAP(3,5,13), NB(5), ND(5), ISER(3,5,13), N1(31)
DIMENSION N2(31), OS(5), DO(31), TR(5)
COMMON LS, ND, NH, IOUT, IEX, ISER, NB, CAP, NEXCH
M = 1
DO 99 L=1, LS
  NMK = N1(IEX(3,L,1))
  X = 1.0/(MASS(3,L,1)*CAP(3,L,1)) - 1.0/(MASS(2,L,NMK)*CAP(2,L,NMK))
  R = AUF(3,L,1)
  DENOM = 1.0-EXP(B*X)
  IF (ABS(DENOM) - 1.0E-06) 1001, 1001, 1002
  TSET = MASS(3,L,1)*CAP(3,L,1)*(TO(3,L,1)-TI(3,L,1))/B+TO(3,L,1)
  GO TO 1003
1001 TSET = -MASS(3,L,1)*CAP(3,L,1)*(TO(3,L,1)-TI(3,L,1))*X/DENOM+
      TO(3,L,1)
1002 NBOI = NB(L)
      DO 1201 NN=1, NBOI
        NDUM = N1(IEX(3,L,NN))
        X = 1.0/(MASS(3,L,NN)*CAP(3,L,NN)) - 1.0/(MASS(2,L,NDUM))*
            CAP(2,L,NDUM)
        B = AUF(3,L,NN)
        DENCM = 1.0-EXP(B*X)
        IF (ABS(DENOM) - 1.0E-06) 2001, 2001, 2002
        TI(2,L,NDUM) = MASS(3,L,NN)*CAP(3,L,NN)*(TO(3,L,NN)-TI(3,L,NN))/B
            + TO(3,L,NN)
        GO TO 2003
2001 TI(2,L,NDUM) = -MASS(3,L,NN)*CAP(3,L,NN)*(TO(3,L,NN)-TI(3,L,NN))*
            X/DENOM + TO(3,L,NN)
2002 IF (ABS((TI(2,L,NDUM)-TSET)/TSET) - 1.0E-05) 12, 12, 11
11 MASS(2,L,NDUM) = (TI(2,L,NDUM)/TSET)*MASS(2,L,NDUM)
    GO TO 2
12 TI(2,L,NDUM) = TSET
1201 CONTINUE
    OS(L) = 0.0

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STDY0001
 STDY0002
 STDY0003
 STDY0004
 STDY0005
 STDY0006
 STDY0007
 STDY0008
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 STDY0010
 STDY0011
 STDY0012
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 STDY0014
 STDY0015
 STDY0016
 STDY0017
 STDY0018
 STDY0019
 STDY0020
 STDY0021
 STDY0022
 STDY0023
 STDY0024
 STDY0025
 STDY0026
 STDY0027
 STDY0028
 STDY0029
 STDY0030
 STDY0031
 STDY0032
 STDY0033
 STDY0034
 STDY0035
 STDY0036

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SUMT = 0.0
SUMM = 0.0
NBOI = NB(L)
DO 13 NN=1,NBOI
  NE = IEX(3,L,NN)
  NA = N1(IEX(3,L,NN))
  DO(NE) = MASS(3,L,NN)*CAP(3,L,NN)*(TO(3,L,NN)-TI(3,L,NN))
  TO(2,L,NA) = TI(2,L,NA) - DO(NE)/(MASS(2,L,NA)*CAP(2,L,NA))
  IF (TO(2,L,NA)-TI(3,L,NN)) 1203,1203,1204
1202 1203 MASS(2,L,NA) = MASS(2,L,NA) + 1.0E-05*MASS(2,L,NA)
      GO TO 1202
1204 QS(L) = QS(L) + DO(NE)
      SUMT = SUMT+MASS(2,L,NA)*TO(2,L,NA)
      SUMM = SUMM+MASS(2,L,NA)
13  CONTINUE
      NDOI = ND(L)
      DO 17 INDX=1,NDOI
        IF (ISER(2,L,INDX)) 16,15,17
15  MASS(2,L,INDX) = SUMM
      GO TO 17
16  WRITE (IOUT,202) L,INDX,ISER(2,L,INDX)
202  FORMAT (1H, ' **INCORRECT DATA VALUE-LOOP:', I2, ', ', NODE:', I3,
1  ', ISER =', I5, ' **')
      IERR = 1
      GO TO 60
17  CONTINUE
      TR(L) = SUMT/SUMM
      NDUM = N1(IEX(3,L,1))
      NDOI = ND(L)
      DO 23 I=1,NDOI
        NF = NDUM - I
        NA = NP+1
        IF (NP) 22,21,20
20  TO(2,L,NP) = TI(2,L,NA)
      TI(2,L,NP) = (TO(2,L,NP)-TAMB)*EXP(AUF(2,L,NP)/(MASS(2,L,NP)*
1  CAP(2,L,NP))) + TAMB

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STDY0037
 STDY0038
 STDY0039
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 STDY0050
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 STDY0061
 STDY0062
 STDY0063
 STDY0064
 STDY0065
 STDY0066
 STDY0067
 STDY0068
 STDY0069
 STDY0070
 STDY0071
 STDY0072


```

21 GC TO 23
   TEO = TI(2,L,NA)
   GO TO 24
22 WRITE (IOUT,203) L,NP,NDUM
203 FORMAT (1H,' **PROBLEM DETECTED IN LOOP:',I2,',', NODE:',I3,
1',', FIRST BRANCH NODE:',I3,', **')
   IERR = 1
   GO TO 60
23 CONTINUE
24 NBIST = NB(L)
   NDUN = N1(IEX(3,L,NBLST))
   NP = NDUM + 1
   TI(2,L,NP) = TR(L)
   TO(2,L,NP) = (TI(2,L,NP) - TAMB) * EXP(-AUF(2,L,NP)) / (MASS(2,L,NP) *
1 CAP(2,L,NP)) + TAMB
   NDCI = ND(L)
   DO 30 I=2,NDOI
   NE = NDUM + I
   NA = NP - 1
   TI(2,L,NP) = TO(2,L,NA)
   IF (NP-ND(L)) 25,26,29
25 TO(2,L,NP) = (TI(2,L,NP) - TAMB) * EXP(-AUF(2,L,NP)) / (MASS(2,L,NP) *
1 CAP(2,L,NP)) + TAMB
   GO TO 30
26 IF (IEX(2,L,NP)) 27,27,28
27 WRITE (IOUT,204) L,NP,IEX(2,L,NP)
204 FORMAT (1H,' **INCORRECT DATA VALUE-LOOP:',I2,',', NODE:',I3,
1',', IEX =',I5,', **')
   IERR = 1
   GO TO 60
28 IF (IEX(2,L,NP) - NEXCH) 2801,2801,2802
2801 TO(2,L,NP) = TEO
   GO TO 31
2802 WRITE (IOUT,204) L,NP,IEX(2,L,NP)
   IERR = 1
   GO TO 60

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STDY0073
STDY0074
STDY0075
STDY0076
STDY0077
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STDY0080
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STDY0082
STDY0083
STDY0084
STDY0085
STDY0086
STDY0087
STDY0088
STDY0089
STDY0090
STDY0091
STDY0092
STDY0093
STDY0094
STDY0095
STDY0096
STDY0097
STDY0098
STDY0099
STDY0100
STDY0101
STDY0102
STDY0103
STDY0104
STDY0105
STDY0106
STDY0107
STDY0108

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29  NFRST = NDUM-NB(L)+1
   WRITE (IOUT,203) L,NP,NFRST
   IERR = 1
   GO TO 60
30  CONTINUE
31  IO 34 INDX=M,NH
   NN = INDX
   IF (IEX(1,1,NN)) 33,32,35
32  TO(1,1,NN) = (TI(1,1,NN)-TAMB)*EXP(-AUF(1,1,NN)/(MASS(1,1,NN)*
1  CAP(1,1,NN))) + TAMB
   NA = NN+1
   IF (NA-NH) 3201,3201,60
3201 TI(1,1,NA) = TO(1,1,NN)
   GO TO 34
33  WRITE (IOUT,205) NN,IEX(1,1,NN)
205  FORMAT (1H, ' **INCORRECT DATA VALUE-HTW LOOP, NODE:',I3,
1  ', IEX =',I5, ' **')
   IERR = 1
   GO TO 60
34  CONTINUE
35  IF (IEX(1,1,NN)-NEXCH) 3502,3502,3501
3501 WRITE (IOUT,205) NN,IEX(1,1,NN)
   IERR = 1
   GO TO 60
3502 NDN = NN-1
   THS = TO(1,1,NDN)
   NP = N2(IEX(1,1,NN))
   X = 1.0/(MASS(2,L,NP)*CAP(2,L,NP))-1.0/(MASS(1,1,NN)*CAP(1,1,NN))
   E = AUF(2,L,NP)
   DENOM = 1.0-EXP(B*X)
   IF (ABS(DENOM)-1.0E-06) 36,36,37
36  TI(1,1,NN) = MASS(2,L,NP)*CAP(2,L,NP)*(TO(2,L,NP)-TI(2,L,NP))/B +
1  TO(2,L,NP)
   GO TO 38
37  TI(1,1,NN) = -MASS(2,L,NP)*CAP(2,L,NP)*(TO(2,L,NP)-TI(2,L,NP))*
1  X/DENOM + TO(2,L,NP)

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STDY0109
STDY0110
STDY0111
STDY0112
STDY0113
STDY0114
STDY0115
STDY0116
STDY0117
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STDY0142
STDY0143
STDY0144

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38 IF (ABS((TI(1,1,NN)-THS)/THS)-1.0E-05) 39,39,41
39 IF (TO(2,L,NN)-THS) 43,40,40
40 TI(1,1,NN) = 1.001*THS
41 NDCI = ND(L)
DO 42 INDX=1,NDOT
  MASS(2,L,INDX) = (TI(1,1,NN)/THS)*MASS(2,L,INDX)
42 CONTINUE
GO TO 1
43 TI(1,1,NN) = THS
  NE = IEX(1,1,NN)
  DO(NE) = MASS(2,L,NN)*CAP(2,L,NN)*(TO(2,L,NN)-TI(2,L,NN))
  TO(1,1,NN) = TI(1,1,NN)-DO(NE)/(MASS(1,1,NN)*CAP(1,1,NN))
  DO 47 I=1,NH
    NA = NN+I
    NE = NA-1
    IF (NA-NH) 44,44,60
    TI(1,1,NA) = TO(1,1,NE)
    IF (IEX(1,1,NA)) 46,45,48
    TO(1,1,NA) = (TI(1,1,NA)-TAMB)*EXP(-AUF(1,1,NA)/(MASS(1,1,NA)*
1 CAP(1,1,NA))) + TAMB
    GO TO 47
46 WRITE (IOUT,205) NA,IEX(1,1,NA)
  IERR = 1
  GO TO 60
47 CONTINUE
48 IF (IEX(1,1,NA)-NEXCH) 50,50,49
49 WRITE (IOUT,205) NA,IEX(1,1,NA)
  IEFF = 1
  GO TO 60
50 M = NA
99 CONTINUE
60 RETURN
END
STDY0145
STDY0146
STDY0147
STDY0148
STDY0149
STDY0150
STDY0151
STDY0152
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STDY0154
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STDY0174
STDY0175
STDY0176
STDY0177

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SUBROUTINE SET(IDES)
REAL LONG, MASS, MU, MGAS
DOUBLE PRECISION T, TIME
DIMENSION ISER(3,5,13), IEX(3,5,13), IPMP(3,5,13), DIA(3,5,13)
DIMENSION LONG(3,5,13), AUF(3,5,13), MASS(3,5,13), TI(3,5,13)
DIMENSION TO(3,5,13), CAP(3,5,13), RHO(3,5,13), MU(3,5,13), ND(5)
DIMENSION NB(5), K1(31), K2(31), L1(31), L2(31), N1(31), N2(31)
DIMENSION QDO(31), AMAS(3,5,13), ATI(3,5,13), ATO(3,5,13)
DIMENSION CONO(3,5,13), CONV(3,5,13), NTB(31), RPE(5)
DIMENSION NU(31,20), TIB(20), PS(6), PREF(6), PEX(6), PP(6), PC(6)
DIMENSION AW(20), RTW(20), AWD(20), RTWD(20), AR(20), RTR(20), AF(20)
DIMENSION RTF(20), MTW(20), MTR(20), BH(20), WA(20), AINFL(20)
DIMENSION WDSO(20), FWLIT(20,5), WSAB(20), RSAB(20), POL(20), NUEX(20)
DIMENSION PREXT(20), FHPX(20), TAIR(25), WV(25), WDIR(25), TSB(25,20)
DIMENSION BUF(25,20), TOL(25,31), TO(31), DPM(5), NABS(31,20)
DIMENSION NCMP(31,20), NRES(31,20), NHPM(31,20), NHWS(31,20)
DIMENSION QL(25,20), ETHL(25), DHW(20), WUF(25,20)
COMMON LS,ND,NH,IOUT,IEX,ISER,NB,CAP,NEXCH,MASS,TI,TO,AUF,K1,K2
COMMON L1,L2,N1,N2,RHO,DIA, LONG,NTB,THW,IERR,TAMB,DTIME,COND,CONV
COMMON KODP,KODE,INIT,IFLO,NTYPE,MU,NPMP,IPMP,MU,TQ,TOB,TIB
COMMON DPM,PP,RPE,PS,PREF,PEX,PC,TCW,HVO,CVO,QHW,QCW,THG
COMMON TCG,MGAS,CAPG,PMF,THI,QHS,QHO,QCO,QDO,PSENS,AMAS
COMMON /ABC/ TIME,T
COMMON /BLD/AW,RTW,AWD,RTWD,AR,RTR,AF,RTF,MTW,MTR,BH,AINFL
COMMON /BLD/WSAB,RSAB,POL,WV,WDIR,IBHR,ALAT,DECL
COMMON /BLD/ASC,AEC,SDF,BUF,WA,WDSO,FWLIT
COMMON /DLD/ETHL,TOL,NCMP,NABS,NRES,NHPM,NHWS,ECMP,EABS,ERES,EHPM
COMMON /DLD/EHWS,NUEX,PREXT,FHPX,DHW,WUF
COMMON /ALD/QL,NTMP,TAIR,TSB
IF (KODE-1) 1000,6,999
1000 CALL QLOAD(KODE,NTYPE,TAMB,IOUT)
KODP = 0
IHF = 25
IHR = 25
HRF = 0.0
CALL DLOAD(KODE,KODP,IHR,IHRL,HRP,IOUT,LS,NB,IEX,NTYPE,MU,TIB,TOB)
SETU0001
SETU0002
SETU0003
SETU0004
SETU0005
SETU0006
SETU0007
SETU0008
SETU0009
SETU0010
SETU0011
SETU0012
SETU0013
SETU0014
SETU0015
SETU0016
SETU0017
SETU0018
SETU0019
SETU0020
SETU0021
SETU0022
SETU0023
SETU0024
SETU0025
SETU0026
SETU0027
SETU0028
SETU0029
SETU0030
SETU0031
SETU0032
SETU0033
SETU0034
SETU0035
SETU0036

```

```

1001 IF (IDES) 1001, 1002, 1001
      KODP = 1
      WRITE (IOUT, 200)
200  FORMAT (1H1, 45X, '***SYSTEM DESIGN CONDITIONS***')
      CALL FLOAD(KODE, KODP, IHR, IHR1, HRF, IOUT, LS, NB, IEX, NTYPE, NU, TIB, TOB)
      WRITE (IOUT, 201)
201  FORMAT (1H1, 10X, 'EXCHANGER', 10X, 'LOAD (DTU/HR)')
1002 DO 2 L=1, LS
      NBOI = NB(L)
      DO 1 N=1, NBOI
      IX = IEX(3, L, N)
      IF (IDES) 1003, 1004, 1003
1003  WRITE (IOUT, 203) IX, TOL(25, IX)
203  FORMAT (13X, I2, 14X, E11.4)
1004  MASS(3, L, N) = TOL(25, IX) / (CAP(3, L, N) * (TO(3, L, N) - TI(3, L, N)))
      CONTINUE
      CONTINUE
      IF (IDES) 1005, 1006, 1005
1005  GO TO 999
1006  QHS = QHS-ETHL(25)
2000  DO 5 ID=1, 3
      DO 4 JD=1, 5
      DO 3 KD=1, 13
      AMAS(ID, JD, KD) = MASS(ID, JD, KD)
      ATI(ID, JD, KD) = TI(ID, JD, KD)
      ATO(ID, JD, KD) = TO(ID, JD, KD)
      CONTINUE
      CONTINUE
      CONTINUE
      ATI(1, 1, 1) = THW
      CALL STDY(AMAS, ATI, ATO, N1, N2, AUF, TAMB, IERR, KODE)
      IF (IERR-1) 6, 999, 6
3     INIT = 1
4     CALL PRESS(AMAS, NTR, DIA, RHO, MU, LONG, IPMP, INIT, IERR, DPM, PP, RPE)
5     IF (IERR-1) 7, 999, 7
6     IF (KODE-1) 8, 99, 999
7

```

```

SETU0037
SETU0038
SETU0039
SETU0040
SETU0041
SETU0042
SETU0043
SETU0044
SETU0045
SETU0046
SETU0047
SETU0048
SETU0049
SETU0050
SETU0051
SETU0052
SETU0053
SETU0054
SETU0055
SETU0056
SETU0057
SETU0058
SETU0059
SETU0060
SETU0061
SETU0062
SETU0063
SETU0064
SETU0065
SETU0066
SETU0067
SETU0068
SETU0069
SETU0070
SETU0071
SETU0072

```

```

8      DO 11 ID=1,3
      DO 10 JD=1,5
      DO 9 KD=1,13
      MASS(ID,JD,KD) = AMAS(ID,JD,KD)
      TI(ID,JD,KD) = ATI(ID,JD,KD)
      TO(ID,JD,KD) = ATO(ID,JD,KD)
      CONTINUE
      CONTINUE
      CONTINUE
      MGAS = QHS/(CAPG*(THG-TCG))
      TCWI = TO(1,1,NH)
      THI = THW
      PMF = QHS/(((CAP(1,1,1)+CAP(1,1,NH))/2.0)*(THI-TCWI))
      CALL PREC(TCG,THG,MGAS,CAPG,QHS,TCWI,THI,IOUT,IERR)
      IF (IERR-1) 12,999,12
      TCW = TCWI
      QHW = RHO(1,1,1)*HVO*CAP(1,1,1)*THW
      QHC = QHW
      OCW = RHO(1,1,NH)*CVO*CAP(1,1,NH)*TCW
      QCO = QCW
      WRITE (IOUT,202)
      FORMAT (1H1,47X,' ***STEADY-STATE SUMMARY***')
      T = IBHR+0.0
      CALL PRV(T,THW,TCW,HVO,CVO,QHW,OCW,THG,TCG,MGAS,CAPG,PMF,THI,PP,
      1 NPMF)
      IHR = 25
      IHR1 = 25
      HRF = 1.0
      KODP = 1
      CALL DLOAD(KODE,KODP,IHR,IHR1,HRP,IOUT,LS,NB,IEX,NTYPE,NU,TIB,TOB)
      IF (IERR-1) 17,999,17
      DO 18 NX=1,NEXCH
      K = K2(NX)
      L = L2(NX)
      N = N2(NX)
      ODO(NX) = MASS(K,L,N)*CAP(K,L,N)*(TO(K,L,N)-TI(K,L,N))
      SETU0073
      SETU0074
      SETU0075
      SETU0076
      SETU0077
      SETU0078
      SETU0079
      SETU0080
      SETU0081
      SETU0082
      SETU0083
      SETU0084
      SETU0085
      SETU0086
      SETU0087
      SETU0088
      SETU0089
      SETU0090
      SETU0091
      SETU0092
      SETU0093
      SETU0094
      SETU0095
      SETU0096
      SETU0097
      SETU0098
      SETU0099
      SETU0100
      SETU0101
      SETU0102
      SETU0103
      SETU0104
      SETU0105
      SETU0106
      SETU0107
      SETU0108

```



```

18      CONTINUE
      DO 19 I=1,NPMP
      PS(I) = PP(I)
      PREF(I) = PP(I)
      PEX(I) = PP(I)
      PC(I) = 0.0
19      CONTINUE
      GO TO 999
99      IFLO = 0
      CALL FLOWS
999     RETURN
      END

```

```

SETU0109
SETU0110
SETU0111
SETU0112
SETU0113
SETU0114
SETU0115
SETU0116
SETU0117
SETU0118
SETU0119
SETU0120

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FLOW0001
FLOW0002
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FLOW0034
FLOW0035
FLOW0036

```

SUPROUTINE FLOWS
REAL LONG, MASS, MU, MGAS
DOUBLE PRECISION T, TIME
DIMENSION ISER(3,5,13), IEX(3,5,13), IPMP(3,5,13), DIA(3,5,13)
DIMENSION LONG(3,5,13), AUF(3,5,13), MASS(3,5,13), TI(3,5,13)
DIMENSION TO(3,5,13), CAP(3,5,13), RHO(3,5,13), MU(3,5,13), ND(5)
DIMENSION NB(5), K1(31), K2(31), L1(31), L2(31), N1(31), N2(31)
DIMENSION COND(3,5,13), CONV(3,5,13), NTB(31), RPE(5)
DIMENSION NU(31,20), TIB(20), PS(6), PREF(6), PEX(6), PP(6), PC(6)
DIMENSION QDO(31), TQ(31), ACC(6), DPM(5)
DIMENSION BMAS(3,5,13), DMAS(3,5,13)
COMMON LS, ND, NH, IOUT, IEX, YSER, NB, CAP, NEXCH, MASS, TI, TO, AUF, K1, K2
COMMON L1, L2, N1, N2, RHO, DIA, LONG, NTB, THW, IERR, TAMB, DTIME, COND, CONV
COMMON KODP, KODE, INIT, IFLO, NTYPE, NU, NPMP, IPMP, MU, TQ, TOB, TIB
COMMON DPM, PP, RPE, PS, PREF, PEX, PC, TCW, HVO, CVO, QHW, QCW, THG
COMMON TCG, MGAS, CAPG, PMF, THI, QHS, QHO, QCO, QDO, PSENS
COMMON /ABC/TIME, T
COMMON /XYZ/BMAS, DMAS
REFM = MASS(1,1,1)
REFI = TO(1,1,1)
IF (IFLO-1) 1, 3, 1
DO 2 N=1, NPMP
  EREF(N) = PP(N)
  PEX(N) = PP(N) + PSENS*(PP(N)-PS(N))
  IF (PEX(N)) 1001, 2, 2
1001 PEX(N) = PP(N)
  CONTINUE
  IF (IFLO-1) 3000, 3, 3000
  IPRE = 0
  IPRX = 0
  CALL ENRG
  IF (IERR-1) 3000, 43, 3000
  INIT = 2
  CALL PRESS(MASS, NTB, DIA, RHO, MU, LONG, IPMP, INIT, IERR, DPM, PP, RPE)
  IF (IERR-1) 4, 999, 4
  IPRM = 0
  
```

FLOW0037
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 FLOW0060
 FLOW0061
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 FLOW0063
 FLOW0064
 FLOW0065
 FLOW0066
 FLOW0067
 FLOW0068
 FLOW0069
 FLOW0070
 FLOW0071
 FLOW0072

```

5      DO 26 K=1,2
        IF (K-2) 5,6,6
        LIM = 1
        GO TO 7
6      LIM = LS
7      DO 25 I=1,LIM
        IF (K-2) 8,9,9
8      NLIM = NH
        GO TO 10
9      NLIM = ND(L)
10     DO 24 N=1,NLIM
        IF (IPMP(K,L,N)) 11,24,12
11     WRITE (IOUT,204) K,L,N,IPMP(K,L,N)
204    FORMAT (1H,' **INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,
1      ', NODE:',I3,', IPMP=',I5,' **')
        IERR = 1
        GO TO 999
12     KC = K
        LC = L
        NC = N
        NF = IPMP(KC,LC,NC)
        PS(NP) = PP(NP)
        IF (ABS(PP(NP)-PREP(NP))/PREP(NP)-.01) 13,13,14
13     PEX(NP) = PREP(NP)
14     FCTR = (3.1416*4.147E08*DIA(KC,LC,NC)**2)/(4.0*LONG(KC,LC,NC))
        DM = MASS(KC,LC,NC)+DTIME*FCTR*(PEX(NP)-PP(NP))
        IF (DM) 1401,1401,1402
1401    DM = MASS(KC,LC,NC)/2.0
1402    PCI = (DM-MASS(KC,LC,NC))/MASS(KC,LC,NC)
        PC(NP) = PC(NP)+PCI
        ACC(NP) = (DM-MASS(KC,LC,NC))/DTIME
        IF (ABS(PC(NP))-0.10) 16,15,15
15     IPRM = IPRM
        PC(NP) = 0.0
16     MASS(KC,LC,NC) = DM
        IF (KC-2) 17,19,19
  
```



```

17 DO 18 NN=1,NH
   IF (IEX(1,1,NN)) 1701,1701,1702
1701 MASS(1,1,NN) = MASS(KC,LC,NC)
   GO TO 18
1702 MASS(1,1,NN) = (DMAS(1,1,NN)/(DMAS(1,1,NN)+BMAS(1,1,NN)))*
18 CONTINUE
   GO TO 24
19 QTLID = 0.0
   NCCR = NB(LC)
   DO 1901 NINE=1,NCCR
   IX = IEX(3,LC,NIND)
   QTLID = QTLID + TQ(IX)
1901 CCNTINUE
   NDOI = ND(LC)
   DO 23 NN=1,NDOI
   IF (ISER(KC,LC,NN)) 20,21,22
20 WRITE (IOUT,205) KC,LC,NN,ISER(KC,LC,NN)
205 FORMAT (1H,'**INCORRECT DATA VALUE-SECTION:',I2,', LOOP:',I2,
1', NODE:',I3,', ISER =',I5,'**')
   IERR = 1
   GO TO 999
21 MASS(KC,LC,NN) = MASS(KC,LC,NC)
   GO TO 23
22 IX = IEX(KC,LC,NN)
   MASS(KC,LC,NN) = MASS(KC,LC,NC)*TQ(IX)/QTLID
23 CONTINUE
24 CONTINUE
25 CONTINUE
26 CONTINUE
29 T = TIME
   IF (IFLO-1) 999,30,999
30 CVOI = CVO+DTIME*(REFM-PMF)/RHO(1,1,NH)
   IF (CVOI) 3001,3001,3002
3001 CVOI = 0.0
   EMFI = MASS(1,1,NH)

```

```

FLOW0073
FLOW0074
FLOW0075
FLOW0076
FLOW0077
FLOW0078
FLOW0079
FLOW0080
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FLOW0084
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FLOW0086
FLOW0087
FLOW0088
FLOW0089
FLOW0090
FLOW0091
FLOW0092
FLOW0093
FLOW0094
FLOW0095
FLOW0096
FLOW0097
FLOW0098
FLOW0099
FLOW0100
FLOW0101
FLOW0102
FLOW0103
FLOW0104
FLOW0105
FLOW0106
FLOW0107
FLOW0108

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FLOW0109
FLOW0110
FLOW0111
FLOW0112
FLOW0113
FLOW0114
FLOW0115
FLOW0116
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FLOW0120
FLOW0121
FLOW0122
FLOW0123
FLOW0124
FLOW0125
FLOW0126
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FLOW0128
FLOW0129
FLOW0130
FLOW0131
FLOW0132
FLOW0133
FLOW0134
FLOW0135
FLOW0136
FLOW0137
FLOW0138
FLOW0139
FLOW0140

```

TCWI = TO(1,1,NH)
OCI = 0.0
GO TO 3003
3002 TCWI = (CVO*RHO(1,1,NH)*TCW+DTIME*(REFM*REFT-PMF*TCW))/(CVOI*
      1 RHO(1,1,NH))
      OCI = CVOI*RHO(1,1,NH)*CAP(1,1,NH)*TCWI
      PMFI = QHS/(((CAP(1,1,1)+CAP(1,1,NH))/2.0)*(THW-TCWI))
3003 THI = THW
      HVOI = HVO+DTIME*(PMF-REFM)/RHO(1,1,1)
      IF (HVOI) 3004,3004,3005
3004 HVOI = 0.0
      PMFI = MASS(1,1,1)
      THWI = THI
      OHI = 0.0
      GO TO 31
3005 THWI = THW
      OHI = HVOI*RHO(1,1,1)*CAP(1,1,1)*THWI
31 CALL PREC(TCG,THG,MGAS,CAPG,QHS,TCWI,THI,IOUT,IERR)
35 IF (IERR-1) 35,43,35
      QCW = OCI
      OHW = OHI
      TCW = TCWI
      THW = THWI
      CVO = CVOI
      HVO = HVOI
      PMF = PMFI
      GO TO 999
43 T = TIME
      CALL PRV(T,THW,TCW,HVO,CVO,QHW,QCW,THG,TCG,MGAS,CAPG,PMF,THI,PEX,
      1 NPMP)
      RETURN
      END
999

```

```

1 RPE)
SUBROUTINE PRESS(MASS,NTB,DIA,RHO,MU, LONG, IPMP, INIT, IERR, DPM, PP,
REAL MASS, MU, LONG
DIMENSION ND(5), DPM(5), IEX(3,5,13), MASS(3,5,13), NTB(31)
DIMENSION DIA(3,5,13), MU(3,5,13), ISER(3,5,13), FF(31), FV(31)
DIMENSION LONG(3,5,13), RHO(3,5,13), IPMP(3,5,13), PP(6), RPE(5)
COMMON LS, NL, NH, IOUT, IEX, ISER
G= 4.147E08
DO 29 K=1,2
IF (K-2) 1,2,2
LIM = 1
GO TO 3
LIM = LS
DO 28 L=1, LIM
IF (K-2) 4,5,5
NLIM = NH
GO TO 6
NLIM = ND(L)
TFD = 0.0
BPLIS = 0.0
DPM(L) = 0.0
DO 27 N=1, NLIM
IF (IEX(K,L,N)) 7,8,9
WRITE (IOUT,200) K,L,N,IEX(K,L,N)
FORMAT (1H, ' **INCORRECT DATA VALUE-SECTION:', I2, ', LOOP:', I2,
1, ' , NODE:', I3, ', IEX=', I5, ' **')
GO TO 99
DM = MASS(K,L,N)
GO TO 10
IX = IEX(K,L,N)
DM = MASS(K,L,N)/NTB(IX)
RE = 4.0*DM/(3.1416*DIA(K,L,N)*MU(K,L,N))
F = 0.184/EXE(0.2*ALOG(RE))
IF (ISER(K,L,N)) 11,14,12
WRITE (IOUT,201) K,L,N,ISER(K,L,N)
FORMAT (1H, ' **INCORRECT DATA VALUE-SECTION:', I2, ', LOOP:', I2,
PRES0001
PRES0002
PRES0003
PRES0004
PRES0005
PRES0006
PRES0007
PRES0008
PRES0009
PRES0010
PRES0011
PRES0012
PRES0013
PRES0014
PRES0015
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PRES0032
PRES0033
PRES0034
PRES0035
PRES0036

```



```

1  ' , NODE: ', I3, ' , ISER= ', I5, ' **' )
GO TO 99
12  IX = IEX (K, L, N)
    FF (IX) = F
13  IF (INIT-1) 14, 14, 13
    F = FF (IX) + FV (IX)
14  AC = 3.1416 * DIA (K, L, N) ** 2 / 4.0
    DP = (F * LONG (K, L, N) * DM ** 2) / (2.0 * RHO (K, L, N) * G * DIA (K, L, N) * AC ** 2)
    IF (IPMP (K, L, N)) 15, 17, 16
15  WRITE (IOUT, 202) K, L, N, IPMP (K, L, N)
202  FORMAT (1H, ' ** INCORRECT DATA VALUE-SECTION: ', I2, ' , LOOP: ', I2,
1  ' , NODE: ', I3, ' , IPMP= ', I5, ' **' )
GO TO 99
16  IP = IPMP (K, L, N)
17  IF (ISER (K, L, N)) 11, 20, 18
18  IF (DP - DPM (L)) 21, 21, 19
19  DPM (L) = DP
GO TO 21
20  TPD = TPD + DP
21  IF (N - NLIM) 27, 22, 22
22  PP (IP) = TPD + DPM (L)
DO 26 NN = 1, NLIM
23  IF (ISER (K, L, NN)) 11, 26, 23
24  IF (INIT-1) 24, 24, 25
    AC = 3.1416 * DIA (K, L, NN) ** 2 / 4.0
    IX = IEX (K, L, NN)
    IM = MASS (K, L, NN) / NTB (IX)
    FP = (DPM (L) * 2.0 * RHO (K, L, NN) * G * DIA (K, L, NN) * AC ** 2) / (LONG (K, L, NN) *
1  DM ** 2)
    FV (IX) = FP - FF (IX)
25  BPDIS = BPDIS + MASS (K, L, NN) / (RHO (K, L, NN) * DPM (L))
    RPE (L) = 1.0 / BPDIS
26  CONTINUE
27  CONTINUE
28  CONTINUE
29  CONTINUE

```

PRES0037
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PRES0064
PRES0065
PRES0066
PRES0067
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PRES0070
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PRES0072

PRES0073
PRES0074
PRES0075
PRES0076

282.

GO TO 999
IERR = 1
RETURN
END

99
999

ENRG0001
ENRG0002
ENRG0003
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ENRG0034
ENRG0035
ENRG0036

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SUBROUTINE ENRG
REAL MASS, LONG
DIMENSION IEX(3,5,13), MASS(3,5,13), CAP(3,5,13), TI(3,5,13)
DIMENSION TO(3,5,13), AUF(3,5,13), K1(31), K2(31), L1(31), L2(31)
DIMENSION N1(31), N2(31), ISER(3,5,13), DIA(3,5,13), LONG(3,5,13)
DIMENSION RHO(3,5,13), NB(5), ND(5), COND(3,5,13), CONV(3,5,13)
DIMENSION NTB(31), TOP(3,5,13), ATD(3,5,13)
DIMENSION BMAS(3,5,13), DHAS(3,5,13), DIFF(3,5,13)
COMMON LS, ND, NH, IOUT, IEX, ISER, NB, CAP, NEXCH, MASS, TI, TO, AUF, K1, K2
COMMON L1, L2, N1, N2, RHO, DIA, LONG, NTB, THW, IERR, TAMB, DTIME, COND, CONV
COMMON /XYZ/ BMAS, DHAS
DO 33 K=1,3
IF (K-2) 1,2,2
LIM = 1
GO TO 3
LIM = LS
DO 32 L=1, LIM
IF (K-2) 4,5,6
NLIM = NH
GO TO 7
NLIM = ND(L)
GO TO 7
NLIM = NB(L)
DO 31 N=1, NLIM
IF (IEX(K,L,N)) 8,27,9
WRITE (IOUT,200) K,L,N,IEX(K,L,N)
FORMAT (1H, ' **INCORRECT DATA VALUE-SECTION:', I2, ', LOOP:', I2,
1, ', NODE:', I3, ', IEX =', I5, ' **')
GO TO 99
IX = IEX(K,L,N)
TMAS = RHO(K,L,N)*3.1416*(DIA(K,L,N)**2)*NTB(IX)*LONG(K,L,N)/4.0
DL = MASS(K,L,N)*DTIME/TMAS
IF (K-2) 10,11,13
KE = K2(IX)
IE = L2(IX)
NE = N2(IX)

```

1

2

3

4

5

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7

8

200

9

10


```

11 GO TO 14
12 IF (ISER(K,L,N)) 12,13,10
13 WRITE (IOUT,202) K,L,N,ISER(K,L,N)
202 FORMAT (1H, ' **INCORRECT DATA VALUE-SECTION: ,I2,', LOOP:',I2,
1 ' , NODE:',I3,', ISER =',I5,' **')
GO TO 99
13 KE = K1(IX)
LE = L1(IX)
NE = N1(IX)
14 TN = TI(K,L,N)-TO(KE,LE,NE)
TD = TO(K,L,N)-TI(KE,LE,NE)
15 IF (ABS(TN)-1.0E-6) 1501,1501,16
1501 IF (TN) 1502,1503,1503
1502 TN = -1.0E-6
GO TO 16
1503 TN = 1.0E-6
16 IF (ABS(TD)-1.0E-6) 1601,1601,17
1601 IF (TD) 1602,1603,1603
1602 TD = -1.0E-6
GO TO 17
1603 TD = 1.0E-6
17 IF (ABS(TN/TD-1.0)-1.0E-06) 1705,1705,1704
1705 DTLM = TN
DTLMX = DTLM
COND(K,L,N) = AUF(K,L,N)*DTLM
CONV(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))
DTC = AUF(K,L,N)*DL*DTLMX/(MASS(K,L,N)*CAP(K,L,N))
GO TO 20
1704 TM=TN/TD
IF (TM) 1701,1701,1703
1701 ATDP = (TN+TD)/2.0
COND(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))
DTLM = COND(K,L,N)/AUF(K,L,N)
IF (ABS(TN)-ABS(TD)) 18,1702,1702
1702 TDX = 0.0
DTLMX = -(TDX+TD)/2.0
ENRG0037
ENRG0038
ENRG0039
ENRG0040
ENRG0041
ENRG0042
ENRG0043
ENRG0044
ENRG0045
ENRG0046
ENRG0047
ENRG0048
ENRG0049
ENRG0050
ENRG0051
ENRG0052
ENRG0053
ENRG0054
ENRG0055
ENRG0056
ENRG0057
ENRG0058
ENRG0059
ENRG0060
ENRG0061
ENRG0062
ENRG0063
ENRG0064
ENRG0065
ENRG0066
ENRG0067
ENRG0068
ENRG0069
ENRG0070
ENRG0071
ENRG0072

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```

1703 DTC = (AUF(K,L,N)*DTIME*TD)/(2.0*TMS*CAP(K,L,N))
18 CONV(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))
19 GO TO 20
    DTLN = (TN-TD)/ALOG(TM)
    COND(K,L,N) = AUF(K,L,N)*DTLN
    CONV(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))
    ALPL = (TN-TD)/DTLN
    TDX = TD*EXP(ALPL*DL)
    IF (ABS(TIX/TD-1.0)-1.0E-06) 1901,1901,1902
1901 DTLN = TD
    GO TO 1903
1902 DTLN = (TDX-TD)/ALOG(TDX/TD)
1903 LTC = AUF(K,L,N)*(TDX-TD)/(MASS(K,L,N)*CAP(K,L,N)*ALPL)
20 FRCN = DTLN/DTLN
    TDCP = TO(K,L,N)+FRCN*DL*(TI(K,L,N)-TO(K,L,N))
    TCF(K,L,N) = TODP-DTC
    ATD(K,L,N) = (TN+TD)/2.0
    IF (K-K1(IX)) 21,21,22
21 IF (TOP(K,L,N)-TI(KE,LE,NE)) 23,23,31
22 IF (TOP(K,L,N)-TI(KE,LE,NE)) 31,24,24
23 TOP(K,L,N) = TI(KE,LE,NE)+1.0E-06
    GO TO 31
24 TOF(K,L,N) = TI(KE,LE,NE) - 1.0E-06
    GO TO 31
27 TMS = RHO(K,L,N)*3.1416*(DIA(K,L,N)**2)*LONG(K,L,N)/4.0
    DL = MASS(K,L,N)*DTIME/TMS
    TN = TI(K,L,N)-TAMB
    TD = TO(K,L,N)-TAMB
    IF (ABS(TN-TD)/TN-.0001) 28,28,29
28 COND(K,L,N) = AUF(K,L,N)*(TN+TD)/2.0
    CONV(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))
    LTC = (AUF(K,L,N)*DTIME*TD)/(TMS*CAP(K,L,N))
    TODE = TO(K,L,N) + DL*(TI(K,L,N)-TO(K,L,N))
    TOP(K,L,N) = TODP-DTC
    ATD(K,L,N) = (TN+TD)/2.0
    GO TO 30

```

ENRG0073
 ENRG0074
 ENRG0075
 ENRG0076
 ENRG0077
 ENRG0078
 ENRG0079
 ENRG0080
 ENRG0081
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 ENRG0083
 ENRG0084
 ENRG0085
 ENRG0086
 ENRG0087
 ENRG0088
 ENRG0089
 ENRG0090
 ENRG0091
 ENRG0092
 ENRG0093
 ENRG0094
 ENRG0095
 ENRG0096
 ENRG0097
 ENRG0098
 ENRG0099
 ENRG0100
 ENRG0101
 ENRG0102
 ENRG0103
 ENRG0104
 ENRG0105
 ENRG0106
 ENRG0107
 ENRG0108

AD-A033 301

MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF NUCLEAR--ETC F/G 9/2
TDIST, A PROGRAM FOR COMMUNITY ENERGY DEMAND ANALYSIS AND TOTAL--ETC(II)
AUG 76 J W STETKAR, M W GOLAY

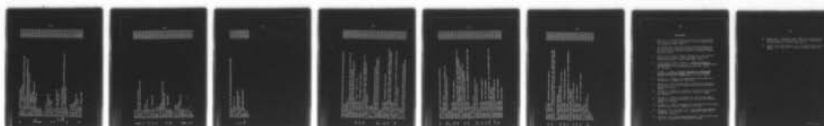
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END

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29      DTLN = (TN-TD)/ALOG(TN/TD)
      COND(K,L,N) = AUF(K,L,N)*DTLN
      CONV(K,L,N) = MASS(K,L,N)*CAP(K,L,N)*(TI(K,L,N)-TO(K,L,N))
      TDX = TD+EL*(TN-TD)
      DTC = (AUF(K,L,N)*DTIME*(TDX+TD))/(2.0*THAS*CAP(K,L,N))
      TODP = TO(K,L,N)+DL*(TI(K,L,N)-TO(K,L,N))
      TOP(K,L,N) = TODP-DTC
      ATD(K,L,N) = (TN+TD)/2.0
      IF (TOP(K,L,N)-TAMB) 3001,3001,31
30      TOP(K,L,N) = TO(K,L,N)
31      CONTINUE
32      CONTINUE
33      CONTINUE
      K = 1
      L = 1
      DO 36 N=1,NH
      TO(K,L,N) = TOP(K,L,N)
      IF (N-1) 34,34,35
34      TI(K,L,N) = THW
      GO TO 36
35      NO = N-1
      IF (IEX(K,L,N)) 502,502,501
      501 TI(K,L,N) = TO(K,L,N)
      GO TO 36
      502 IF (IEX(K,L,N)) 501,501,503
      503 TI(K,L,N) = (DMAS(K,L,NO)*TO(K,L,NO)+BMAS(K,L,NO)*TI(K,L,NO))
      1 / (DMAS(K,L,NO)+BMAS(K,L,NO))
36      CONTINUE
      K = 2
      DO 47 L=1,LS
      NDOI = ND(L)
      DO 46 N=1,NDOI
      TO(K,L,N) = TOP(K,L,N)
      IF (N-1) 37,37,38
37      NO = ND(L)
      TO(K,L,NO) = TOP(K,L,NO)

```

ENRG0109
 ENRG0110
 ENRG0111
 ENRG0112
 ENRG0113
 ENRG0114
 ENRG0115
 ENRG0116
 ENRG0117
 ENRG0118
 ENRG0119
 ENRG0120
 ENRG0121
 ENRG0122
 ENRG0123
 ENRG0124
 ENRG0125
 ENRG0126
 ENRG0127
 ENRG0128
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ENRG0174
ENRG0175
ENRG0176
ENRG0177
ENRG0178

```

38 GO TO 39
39 NO = N-1
40 IF (ISER(K,L,NO)) 40,41,42
41 WRITE (IOUT,202) K,L,NO,ISER(K,L,NO)
42 GO TO 99
43 NS = NO
44 NL = NS+NB(L)
45 IF (N-NL) 43,43,44
46 NO = NO-1
47 GO TO 39
48 TI(K,L,N) = TO(K,L,NS)
49 GO TO 46
50 SUMT = 0.0
51 SUMM = 0.0
52 NF = N-NB(L)
53 DO 45 NA=NF,NL
54 SUMT = SUMT+MASS(K,L,NA)*TO(K,L,NA)
55 SUMM = SUMM+MASS(K,L,NA)
56 CONTINUE
57 TI(K,L,N) = SUMT/SUMM
58 CONTINUE
59 CONTINUE
60 K = 3
61 DO 49 L=1,LS
62 NBOI = NB(L)
63 DO 48 N=1,NBOI
64 TO(K,L,N) = TOP(K,L,N)
65 CONTINUE
66 CONTINUE
67 IERR = 0
68 GO TO 51
69 IERR = 1
70 RETURN
71 END

```

```

PREC0001
PREC0002
PREC0003
PREC0004
PREC0005
PREC0006
PREC0007
PREC0008
PREC0009
PREC0010
PREC0011

```

```

SUBROUTINE PREC(TCG,THG,NGAS,CAPG,QHS,TCWI,THI,IOUT,IERR)
REAL MGAS
IF (TCG-TCWI) 1,1,2
TCG = TCWI
MGAS = QHS/(CAPG*(THG-TCG))
IF (THG-THI) 3,3,999
THG = THI
MGAS = QHS/(CAPG*(THG-TCG))
IERR = 0
RETURN
END

```

```

1
2
3
999

```



```

SUBROUTINE PRV (T, THW, TCW, HVO, CVO, QHW, QCW, THG, TCG, NGAS, CAPG, PMF,
1 TH1, FF, NEMP)
REAL MASS, MGAS
DCUELE PRECISION T
DIMENSION NB(5), MASS(3,5,13), CAP(3,5,13), TI(3,5,13), TO(3,5,13)
DIMENSION ND(5), ISER(3,5,13), IEX(3,5,13), PP(6)
COMMON LS, ND, NH, IOUT, IEX, ISER, NB, CAP, NEXCH, MASS, TI, TO
WRITE (IOUT, 200) T
FORMAT (1H1, 50X, ' TIME = ', F7.3, ' HR')
WRITE (IOUT, 201)
FORMAT (1H0, 48X, ' **CONSUMER BRANCH DATA**')
WRITE (IOUT, 202)
FORMAT (1H0, ' LOOP', 2X, ' NODE', 2X, ' INLET TEMPERATURE (F)', 7X,
1 ' CUTLET TEMPERATURE (F)', 7X, ' MASS FLOW (LBM/HR)', 7X,
2 ' HEAT DEMAND (BTU/HR)')
DO 2 L=1, LS
NBOI = NB(L)
DO 1 N=1, NBOI
OD = MASS(3, L, N) * CAP(3, L, N) * (TO(3, L, N) - TI(3, L, N))
WRITE (IOUT, 203) L, N, TI(3, L, N), TO(3, L, N), MASS(3, L, N), QD
FORMAT (3X, 12, 3X, 13, 13X, F7.2, 22X, F7.2, 17X, E11.4, 14X, E11.4)
CONTINUE
CONTINUE
WRITE (IOUT, 204)
FORMAT (1H0, 48X, ' **SECONDARY LOOP DATA**')
WRITE (IOUT, 205)
FORMAT (1H0, ' LOOP', 4X, ' SUPPLY TEMP', 4X, ' RETURN TEMP', 4X, ' MASS FLO
1W', 4X, ' HEAT DEMAND', 8X, ' NODE', 4X, ' SUPPLY TEMP', 4X, ' RETURN TEMP',
1 4X, ' MASS FLOW')
WRITE (IOUT, 206)
FORMAT (1H, 13X, ' (F)', 12X, ' (F)', 9X, ' (LBM/HR)', 6X, ' (BTU/HR)', 21X,
1 ' (F)', 12X, ' (F)', 9X, ' (LBM/HR)')
DO 5 L=1, LS
NL = ND(L)
OD = MASS(2, L, NL) * CAP(2, L, NL) * (TO(2, L, NL) - TI(2, L, NL))
WRITE (IOUT, 207) L, TO(2, L, NL), TI(2, L, NL), MASS(2, L, NL), QD

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PRVN0001
 PRVN0002
 PRVN0003
 PRVN0004
 PRVN0005
 PRVN0006
 PRVN0007
 PRVN0008
 PRVN0009
 PRVN0010
 PRVN0011
 PRVN0012
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 PRVN0014
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 PRVN0028
 PRVN0029
 PRVN0030
 PRVN0031
 PRVN0032
 PRVN0033
 PRVN0034
 PRVN0035
 PRVN0036

```

207 FORMAT (4X,I1,7X,F7.2,8X,F7.2,5X,E11.4,3X,E11.4)
DO 4 N=1,NL
IF (ISER(2,L,N)) 4,4,3
3 WRITE (IOUT,208) N,TI(2,L,N),TO(2,L,N),MASS(2,L,N)
208 FORMAT (73X,I2,7X,F7.2,8X,F7.2,5X,E11.4)
4 CONTINUE
5 CONTINUE
209 WRITE (IOUT,209)
FORMAT (1H0,51X,' **HTW LOOP DATA**')
WRITE (IOUT,210)
210 FORMAT (1H0,' SUPPLY TEMPERATURE (F)',9X,'RETURN TEMPERATURE (F)',
1 9X,'TOTAL HEAT DEMAND (BTU/HR)',9X,'MASS FLOW (LBM/HR)')
QD = MASS(1,1,1)*CAP(1,1,1)*(TI(1,1,1)-TO(1,1,NH))
211 WRITE (IOUT,211) TI(1,1,1),TO(1,1,NH),QD,MASS(1,1,1)
FORMAT (9X,F7.2,24X,F7.2,22X,E11.4,20X,E11.4)
WRITE (IOUT,212)
212 FORMAT (1H0,30X,' NODE',6X,'INLET TEMPERATURE (F)',6X,'OUTLET TEMP
ERATURE (F)')
DO 7 N=1,NH
IF (IEX(1,1,N)) 7,7,6
6 WRITE (IOUT,213) N,TI(1,1,N),TO(1,1,N)
213 FORMAT (33X,I2,13X,F7.2,21X,F7.2)
7 CONTINUE
WRITE (IOUT,214)
214 FORMAT (1H0,51X,' **RESERVOIR DATA**')
WRITE (IOUT,215)
215 FORMAT (1H0,51X,' HOT WATER STORAGE')
WRITE (IOUT,2150)
2150 FORMAT (1H0,14X,' WATER TEMPERATURE (F)',15X,'STORAGE VOLUME (CU.F
IT.)',15X,'STORED HEAT (BTU)')
WRITE (IOUT,2151) THW,HVO,QHW
2151 FORMAT (21X,F7.2,27X,E11.4,25X,E11.4)
WRITE (IOUT,216)
216 FORMAT (1H0,51X,' COLD WATER STORAGE')
WRITE (IOUT,2150)
WRITE (IOUT,2151) TCW,CVO,QCW

```

```

PRVN0037
PRVN0038
PRVN0039
PRVN0040
PRVN0041
PRVN0042
PRVN0043
PRVN0044
PRVN0045
PRVN0046
PRVN0047
PRVN0048
PRVN0049
PRVN0050
PRVN0051
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PRVN0063
PRVN0064
PRVN0065
PRVN0066
PRVN0067
PRVN0068
PRVN0069
PRVN0070
PRVN0071
PRVN0072

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PRVN0073
 PRVN0074
 PRVN0075
 PRVN0076
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 PRVN0089
 PRVN0090
 PRVN0091
 PRVN0092
 PRVN0093
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 PRVN0095
 PRVN0096
 PRVN0097
 PRVN0098
 PRVN0099

```

217 WRITE (IOUT,217)
    FORMAT (1H0,46X,' **PRECOOLER GAS-SIDE DATA**')
218 WRITE (IOUT,218)
    FORMAT (1H0,' HELIUM INLET TEMPERATURE (F)',6X,' HELIUM OUTLET TEMP
1ERATURE (F)',6X,' HELIUM MASS FLOW (LBM/HR)',6X,' HEAT FLOW (BTU/HR)
2')
    QD = MGAS*CAPG*(THG-TCG)
    WRITE (IOUT,219) THG,TCG,MGAS,QD
219 FORMAT (10X,F7.2,28X,F7.2,23X,E11.4,17X,E11.4)
    WRITE (IOUT,220)
220 FORMAT (1H0,45X,' **PRECOOLER WATER-SIDE DATA**')
    WRITE (IOUT,221)
221 FORMAT (1H0,14X,' INLET TEMPERATURE (F)',15X,' OUTLET TEMPERATURE (
1F)',15X,' MASS FLOW (LBM/HR)')
    WRITE (IOUT,222) TCW,THI,PMF
222 FORMAT (21X,F7.2,30X,F7.2,25X,E11.4)
    WRITE (IOUT,223)
223 FORMAT (1H0,53X,' **PUMP DATA**')
    WRITE (IOUT,224)
224 FORMAT (1H0,45X,' PUMP',10X,' PRESSURE (PSI)')
    DO 8 I=1,NPMP
    P = PP(I)/144.0
    WRITE (IOUT,225) I,P
225 FORMAT (48X,I2,12X,E11.4)
    CONTINUE
    RETURN
    END
  
```


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